TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

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TRANSACTIONS

INSTITUTION OF CIVIL ENGINEERS
OF IRELAND.

[5th November, 1902.]

MR. JOHN H. RYAN, President, in the Chair.

A VOTE of condolence with the widow and family of the late MR. JOHN NEWBIGGING, Associate Member, was passed on the motion of MR. G. T. MOORE, seconded by MR. CHARLES B. CLANCY.

The following candidates were balloted for and duly elected :—

MR. HENRY BROWNE, as Associate Member ; MR. GEORGE BROWNE, as Associate

The HON. SECRETARY read the Report of MR. W. R. MAGUIRE, Associate, the Institution delegate to the Sanitary Congress at Manchester, who wrote regretting his inability to deliver his Report in person.

DELEGATE'S REPORT ON THE PROCEEDINGS OF THE NINE-TEENTH CONGRESS OF THE SANITARY INSTITUTE OF GREAT BRITAIN, HELD AT MANCHESTER FROM SEPT. 9TH TO 13TH, 1902.

To the President and Council of the Institution of Civil Engineers of Ireland.

GENTLEMEN,—I had the pleasure, at your desire, to attend · this Congress as one of your Delegates; altogether 2,100

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Delegates and Members were present, and the Congress was most successful, notwithstanding the simultaneous Meeting of the British Association in Belfast and the general multiplication of such gatherings year by year.

The formal reception by the Lord Mayor of Manchester of Delegates and Members took place in the Town Hall, and the Inaugural Address was delivered by Earl Egerton of Tatton, in the Whitworth Hall at Owens College, where the chief work of the Congress was carried out during the week.

The usual hospitalities were cordially extended to the Members of the Congress by Lord Egerton, the Lord Mayor of Manchester, the Mayor of Salford, &c. Numerous visits to inspect municipal undertakings and various interesting excursions were arranged. One of the Past Presidents of this Institution—John Audley Frederick Aspinall, General Manager of the Lancashire and Yorkshire Railway Company, kindly arranged for an inspection of the new Engineering Works of that Company at Horwich. These magnificent Works were designed, built and completed by Mr. Aspinall, and are perfect in every detail. As your Delegate I felt proud of belonging in any way to an Institution which can boast of a Past President capable of creating and controlling so vast a centre of engineering industry.

It is, of course, impossible to refer in this brief Report to all the Conferences held and Papers considered at this Congress, but I may suggest to those interested in such matters that the Papers on the Construction of Sanatoria for Tuberculosis and on the prevention and treatment of that dreadful scourge of our nation are well worth careful perusal.

Among such important subjects as Bacteriology, Isolation Hospitals, Sewer Ventilation, Sanitation of Road Traffic, Underground Waters, Water Supply, Refuse Disposal, Smoke Abatement, Housing of the Poor, School Hygiene, it appeared to me that the question of Sewage Purification and Disposal

occupied the first place, and was treated in the various papers read and considered at the joint discussion of the sections with conspicuous ability by engineers having long and wide experience.

The City of Manchester and Town of Salford are densely populated centres, and being situated far from the sea present all possible difficulties in regard to a satisfactory purification and disposal of the immense volume of sewage they produce. Different methods have been adopted in each, and the engineers and experts responsible for each installation presented the results of long series of experiments, giving data of immense value to sanitary engineers, and made available for everyone to adopt. Papers were read by Professor Robinson, M.I.C.E., on "Biological Purification of Sewage;" by Mr. J. Corbett, Borough Engineer of Salford, on "Some Sewage Purification Experiments," in which he states that the Salford Sewage Experiments have continued almost without intermission from May, 1889, to present date. They had to treat the sewage of a manufacturing town of nearly a quarter of a million of inhabitants, where trade wastes in great variety were admitted to the sewers, and a large quantity of mere land water entered the sewers. The sewage works were constructed about 20 years ago on a site of only 34 acres, and any additional land would be very costly and difficult to acquire. They had the great advantage of a wharf on the Ship Canal adjoining the sewage works, from which sludge &c., is shipped to sea at a moderate cost. The sewage works were still incomplete, and excellent results attained during many years of experimenting were not yet attained in the daily working on a large scale. When the requisite machinery, &c., was provided, they had no doubt that results as good as those from experiments would be obtained with the whole flow of sewage, and even with a considerable addition of storm water at times, and thus the long-continued experi-

ments would result in a sewage-purification system more economical in first cost, and probably also in working cost, than any system yet adopted in a large manufacturing town.

The conclusion drawn by Mr. Corbett from Salford experiments are—that for densely populated districts tanks or filters of one kind or other are preferable to sewage farms, and more economical; that no patent material for filters is worth its cost; and that cinders of a suitable kind are the very best material for filters or bacteria beds. For precipitation, the best and cheapest results are attained by the use of lime and a salt of iron, either sulphate of iron (called copperas) or chlorate of iron. The sludge is then sent to sea, as cheaper than dealing with it on extensive contact beds, tanks or other apparatus entailing heavy cost for construction or for purchase of land.

At Salford, the precipitation tank effluent is passed through roughing filters of gravel, 3 feet deep, to intercept particles of rag, wood, straw, &c., that would tend to choke the final filters. The final filters are formed of cinders. Various depths of 3′ 6″, 5′, and 8′ were tried, the greater depth proving most efficient; and sprinklers are used to distribute the effluent on the filters.

Another very interesting paper is a "Description of the New Works for the Biological Treatment of the Sewage of Manchester," by J. P. Wilkinson, A.M. Inst. C.E., Engineer of the Works; and also by G. J. Fowler, M.Sc., "A *Résumé* of the Manchester Experiments of Sewage from Chemical and Bacteriological Standpoints."

The Manchester Sewage Experiments are full of interest, for they have been conducted and recorded with systematic care during many years by the most experienced and capable observers. The facts detailed in the papers presented to the Congress are most instructive. This sewage is different in

character to that of ordinary towns, as many trade effluents discharge into the sewers and remain unaffected by the lime and copperas treatment at the outfall works ; but in some cases they are antiseptic and non-putrefactive effluents, and mutually tend to precipitate one another, reducing the amount of chemicals required to a minimum, or to an average rate of 3·34 grains of lime and copperas per gallon.

There are 176 acres of land available at the Davyhulme Sewage Works—comprising 7 acres of precipitation tanks, 15 acres of buildings and sludge tanks, &c., 5 acres of wharf and lay-byes, 26 acres storm water filter area, 46 acres first contact bacteria beds, in course of construction. There are yet to be 46 acres second contact bacteria beds at Flixton, and 100 acres irrigation area at Flixton and Carrington.

In Manchester, on a drainage area of 11,800 acres, resides a population of 564,000, having a water supply of 29 gallons per head per day, using 1,700 miles of sewers, varying from 14 ft. × 10 ft. 6 inches to 9 inches diameter. There are 74,000 pail closets and 46,000 water-closets and 90,000 street traps. The rainfall averages 33 inches. Average daily flow, including storm water, 34 million gallons ; average dry weather flow, 25 million gallons. One day in 1900, 163 million gallons passed to the outfall.

Seven years ago the works came into operation. Screens and catch-pits first intercept detritus and flotage of the sewage ; then it is treated with lime and copperas. Precipitation takes place in tanks, from whence the sludge is pushed by manual labour into channels leading to ejectors, and thence forced by pneumatic pressure into two storage tanks on a higher level near the Ship Canal wharf at Barton Locks ; about 200,000 tons per annum is discharged by gravitation through 24-inch diameter iron pipe into the sludge steamer, and taken down the canal to sea, making about three trips a week. £500 per annum is paid as

dues to the Ship Canal Co., and £1,800 per annum wages to the captain and crew of the sludge steamer.

The cost of the Manchester sewage disposal by precipitation and sludge disposal at sea, as at present carried on, is £1 9s. 8½d. per million gallons. The capital cost of the site of the sewage works, tanks, and equipment at Davyhulme, exclusive of the new filter beds now being constructed, was £230,000. This system, however, has been found to be insufficient and inadequate to render the effluent sufficiently pure for delivery into such a receiver as the Ship Canal, already considerably polluted from other sources, and has long been a subject of complaint ; and here I may say it would be a matter of great practical importance if the authorities would recognise the differential character of the outfalls for sewage, varying from the open sea and the rushing full-flowing river to the smaller stream and the almost stagnant waters of canals. The standard of purity required should be modified to suit the different character of outfalls.

In May, 1898, Mr. Baldwin Latham, Engineer ; Professor Percy Frankland, Bacteriologist ; and Professor W. H. Perkin, junr., Chemist, were appointed as experts by the Manchester County Council to advise on the general question of Manchester sewage disposal. After elaborate and prolonged experiments, which have assumed great public importance, they concluded that " The Bacterial System " is the best adapted for the purification of Manchester sewage.

That the bacteria processes are best conducted in several stages, viz. :—

Settlement and screening out of the grosser solids ;
Anærobic decomposition in the septic tank ;
Oxidation on bacteria beds.

More than one contact with bacteria beds is necessary for the Manchester sewage, but the secondary beds may be of much smaller extent than the primary beds.

It was determined also by these experiments :—

That effluents from closed or open septic tanks are practically identical in composition ;

That with a tank space equal to ha'" the flow of Manchester sewage it is possible to digest 25 per cent. of total suspended matter in sewage ;

That the suspended matter in the septic tank effluent is of a granular character, and readily separates out on standing, and when arrested on the surface of the bacteria bed does not seriously impede the free flow of water into the bed ;

That the organic matter in solution is much more easily nitrified than that present in fresh sewage, so that it is possible with one contact to constantly obtain non-putrefactive filtrates ;

That the blending which takes place in the septic tank is of value in minimising the effect of excessive amounts of manufacturing refuse and in producing an effluent of fairly constant composition ;

That the capacity of contact beds suffers a rapid decrease, but afterwards the rate of decrease is much reduced.

Five causes of loss of capacity were specified as observed during experiments :—

Settling together of the material laid down on the beds ; growth of organisms ; impaired drainage ; insoluble matter entering the bed ; breaking down of material.

To meet these causes special methods of procedure were recommended which cannot be detailed here. The provision for storm water was also fully explained. The bacteria beds improve so that the amount of effluent dealt with can be gradually increased. 400,000 gallons of effluent per day per acre can be received on the beds which have been longest at work.

In the new works, which are at present under construction, 5 additional precipitation tanks, 300 feet × 100 feet × 6 feet,

are provided; 92 bacteria beds for first contact of half an acre each, with 3 feet depth of clinkers over channels formed in the concrete bottom, laid in radial lines; 26 acres of storm water filter beds at Davyhulme. A conduit from the first contact beds at Davyhulme to the second contact beds at Flixton follows the course of the Ship Canal, and is 13 feet wide, with gradient of 1 in 5,000, conveying 63 million gallons per day; 46 acres second contact bacteria beds at Flixton and 100 acres of irrigation lands and works complete the arrangements to deal effectually with the maximum flow of 126 million gallons per day.

The sluice arrangements are such that they can be worked automatically or by hand, and electric lighting is provided near the sluices, and to light the transit passages at night.

By these works, when completed, it has been shown that the sewage of Manchester will be so purified that the effluent can flow harmlessly into the Ship Canal. The cost of these new works will be £490,000.

I give this brief *résumé* simply to draw attention to the importance of the practical experiments proceeding at Salford and Manchester in the hope that some Member better qualified than I am may be induced to bring the question and the answer as regards the best means of sewage disposal fully before the Institution.

I beg to conclude my Report with thanks for the honour conferred upon me in delegating me to act as your representative at the Manchester Congress.

I am,

Yours faithfully,

WM. R. MAGUIRE.

30th September, 1902.

A vote of thanks to MR. MAGUIRE was cordially adopted.

ANNUAL GENERAL MEETING.

MR. JOHN H. RYAN, President, in the Chair.

The Officers and Council for 1903 were balloted for and duly elected.

(*See* List of Members.)

The following transfers were notified by the Council :—

GEORGE MARSHALL HARRISS, from class of Associates to class of Members.

WILLIAM PATRICK HADE, from class of Associate Members to class of Members.

WILLIAM HARRISON HARGRAVE, JOHN ROCHFORD, and HERBERT T. HARRIS, from the class of Associates to the class of Associate Members.

The following candidates were balloted for and duly elected :—

GEORGE A. E. HICKSON, as Member ; RUDOLPH M. BUTLER, JOHN JOSEPH INGLIS, and RICHARD LLOYD HUGHES, as Associate Members.

On the motion of MR. J. DILLON, Past President, seconded by MR. J. P. GRIFFITH, Past President, a resolution was passed relieving Messrs. C. P. Cotton, B. B. Stoney, and Alexander M'Donnell from their position as Trustees of the Mullins' Trust Fund, in accordance with their wishes, and appointing in their place Messrs. John H. Ryan, Robert Cochrane, and William Ross, and authorising the Law Agents to take any steps necessary to give legal effect to the resolution.

The President delivered his Address as follows :—

GENTLEMEN,

I have again to thank you for the great distinction you have conferred upon me last year by electing me to the honourable office of President of this Institution.

On looking over the Annals I find that the name of the *Institution of Civil Engineers of Ireland* was adopted in 1844 by the then *Civil Engineers' Society of Ireland*, which was founded on the 6th of August, 1835, with Col. John Fox Burgoyne as Chairman. We may, therefore, say that our Institution is 67 years old. It appears that in the earlier years of its history, and up to the year 1853, the Institution occupied rooms in the Custom House, Dublin, kindly placed at its disposal by the Commissioners of Public Works. In that year it transferred its quarters to 41 Upper Sackville-street, where meetings were held up to 1861. Since which date, and up to 1879, rooms were provided in Trinity College, where meetings were also held.

A Royal Charter was obtained in 1879, and in that year the Institution moved into these premises we at present occupy, a long lease of which, thanks to the liberality of one of our Past Presidents—the late Mr. Bernard Mullins (1859–60), we have been enabled to acquire. Up to 1891 we were indebted to the kindness of the Board of Trinity College for the use of the hall of the Engineering School in which to hold the evening meetings.

The Institution decided to build a suitable hall in connection with its own premises, and in 1891 this spacious hall was opened for evening meetings, now held regularly every month during the Session ; and to the liberality of one of our Past Presidents—Mr. Wilson—we are in a large measure indebted for the comfortable room at the rere, which was completed in 1899. As you will notice, the hall has, within

the last few weeks, been decorated and made more attractive,
while the room at the rere has been comfortably furnished
during the last year, and now forms the library and reading
room. It is open during the day and two evenings in the
week as a place not only for reading, but for rendezvous and
conversation ; the latest engineering periodicals and books
are provided, the Institution having granted a sum of £50
for this purpose, so that members can now keep *au courant*
with the engineering literature of the day. I am glad to
inform you that the membership of the Institution is steadily
increasing, and it now numbers a total of 244, made up as
follows :—Members, 143 ; Associate Members, 47 ; Associates,
54. There are also enrolled 3 Honorary Members.

In thus briefly reviewing the history of the Institu-
tion, it is—using the words of your Past President,
Mr. Griffith—" with the hope of increasing your interest
in it, and stimulating you to further exertions for
its advancement." Your Council are using every
endeavour to forward the interests of the Institution,
and to keep up the standard of its membership; and
while on this point, and before concluding this portion of
my Address, I wish to call attention to the importance of
members abandoning the practice of appending the letters
" C.E." to their names, which letters are meaningless, since
any unqualified person can use these letters, but to append
to their names the recognised abbreviated designation of
their class, " M. Inst. C.E.I.," " Assoc. M. Inst. C.E.I.,"
" Associate Inst. C.E.I.," and which designations your
Council, by a strict interpretation of the Bye-laws of the
Institution, endeavour to select such candidates as are worthy
to become members of the Institution. And in the selection
of candidates to fill appointments under District Councils,
your Institution should urge upon the Local Government
Board the necessity, even in the interests of the health of

the community, to sanction appointments only of such
candidates who at least come up to the qualifications we
impose, irrespective of political or religious opinions.

Only a century or so ago our profession was indefinite in
its scope, and was then affiliated with architecture, the art
of war, &c. ; architects then built bridges, and laid out towns
and cities. The military engineer alone was exclusively em-
ployed in constructing means of communication between
towns and countries, and practically doing what we civil
engineers do to-day. By degrees civil engineering, as dis-
tinguished from military engineering, was evolved as a
distinct profession, and shortly afterwards these three depart-
ments of knowledge crystallised into the respective channels
which they occupy to-day.

After the invention of the steam engine and its develop-
ment mechanical engineering branched off as a speciality,
and now there are of late years younger shoots from the
same branch—such as marine engineering, electrical engineer-
ing, which, judging by recent discoveries and inventions,
will branch off into still further off-shoots.

The development of scientific geology and research has
gradually produced the mining engineer and the chemical
engineer, and so on.

Although this infinite variety of subjects is creating an
ever-increasing diversity of occupations, yet there is a corres-
ponding increase in that bond of union which will hold all
engineers together, a common ground on which we must
always meet—that is, the science of mechanics in its broadest
sense.   We are all obliged to construct our works, our
machines, and regulate their actions with like materials and
forces given by nature for the service of man. The qualities
of materials, and the laws regulating various forms of force
and energy are the common property of all engineers ; one
branch can receive the matured results of another, and then

readily apply them to its own purpose. Mining engineers appropriate the discoveries of chemical research. Mechanical and civil engineers are dependent on the science of metallurgy for their *raison d'être*. Metals would have remained buried in the earth, unworked and unworkable, if the mechanical engineer had not supplied the pumping, drilling and other machines which made mining practicable; the mining engineer the knowledge of geology and metallurgy which allowed the machines so provided to be used to their fullest capacity ; and the civil engineer the means of rapidly and safely transporting them. Electrical engineers are applying the data supplied by physics and mechanics, mechanical engineers, civil engineers, and railway engineers are in turn applying their results in a number of ways to increase the safety and comfort of travelling ; and so on. Development in one branch of science tends to development in others.

After this general review of the manner in which engineering progress shows itself, I will now endeavour to enumerate a few of the special and most important achievements of the past year or two, although I feel that I am merely traversing ground already traversed by the numerous engineering and scientific periodicals and kindred societies of the day.

First, as to bridge building, the palm must be awarded to the United States—one of the most notable structures being that of the New Kinzua Viaduct, which is 2,053 feet long and at one point 300 feet high. The famous old viaduct— so graphically described by your former President, Mr. Mills, in his Inaugural Address—recently became too weak for the heavy coal traffic passing over it, and it has been replaced by a new one, with its towers resting on the old masonry. There are twenty of these towers, having riveted connections throughout.

A floating drawbridge has been built at Northwich,

England, at a place where it is impossible to maintain spans on masonry piers, owing to the settlement of the ground which follows the pumping from brine wells. The 112 feet swing span is supported on a circular pontoon, and its motion controlled by wheels running on a truck resting on piles.

The International Bridge, by which the Grand Trunk Railway crosses the Niagara River at Buffalo, had ten spans with a total length of about 2,300 feet, and was built 30 years ago. They had phœnix columns, and cast-iron connection blocks at the panel points, and were too light to carry satisfactorily the heavy loads of to-day. They were accordingly replaced during 1900-1 with heavier trusses, by a novel method. A temporary steel span was built outside one of the old spans, the floor system suspended from it, and the old structure then replaced by the new. When this span was in position the erecting trusses were moved to the next span, and the process there repeated, in this way avoiding any material interference with the traffic.

In suspension bridges the new East River Bridge, now being built between New York and Brooklyn, is the largest highway-suspension structure in the world. The bridge will cost for the structure alone £1,600,000, and including property acquired £2,700,000. The extreme length of the bridge is between terminals 7,200 feet—length of river span, 1,600 feet, extreme width, 118 feet. Each tower is 333 feet above high water level, and weighs 3,000 tons apiece. In sinking the foundations for the piers some parts of the work were carried on at a depth of 100 feet; within 15 feet of the limit of the depth it is possible for workmen to do this kind of work. The suspension span will have four cables, each of 37 strands, and each strand having 281 wires, or 10,397 wires to each cable, and the diameter of each cable will be 18¼ inches. The wire in the bridge will have a tensile strength of 200,000 ℔s. per square inch. The structure will be com-

pleted in two years, and will be one of the triumphs of the twentieth century. The Inter-provincial Bridge piers at Ottawa afford examples of masonry work done under particularly trying conditions. The bridge is 2,287 feet long, with a main 556 feet cantilever span, two 257 feet anchor spans, a 247 feet and a 140 feet truss span and plate girder approaches. Two of the piers were sunk through 30 inches of ice in shallow water, a third was built during low water directly on the rock without a crib, while the others were sunk through 20 to 30 feet of sawdust by means of very high cribs.

The hydraulic branch of engineering has had some large and important works under construction, the most notable, perhaps, being that of the Assuan and Assiut dams or barrages across the Nile. The Assuan dam is built of granite masonry, 130 feet high, with 180 sluices capable of holding up 35 million cubic feet of water. The regulation of the sluices will be performed by self-balanced roller gates weighing 14 tons each, designed by our distinguished countryman, Mr. Stoney. The maximum flood of 275,000 cubic feet per second will be discharged through these sluices at a velocity of 20 feet per second, and ordinary floods at 16 feet per second.

The building of railways throughout the world has been as active as hitherto, and probably more so when one recalls that stupendous undertaking—the Siberian railway, extending from Russia on the West, to the Pacific Ocean in the East, traversing a region hitherto comparatively unknown, which will open up a country rich in mineral and other resources.

In China, before the recent outbreak with that country, railway concessions had been at last granted by the Chinese Government, and several lines of railway projected and some under construction. These projects have again been started,

and China bids fair to become an immense field for railway enterprise.

In South Africa also, and we may add Egypt and the Soudan, railway enterprise is notably depicted by the exploring and construction of the Cape to Cairo Railway, and the Uganda Railway, and other vast schemes of railway construction are now contemplated for the opening up of South Africa, which had been checked by the late war. The Transvaal and Orange Free State, having been absorbed into the British Dominions, form a grand field for the rising generation for the practice of all branches of our profession. The magnificent prospects thus disclosed forms a rich heritage in which the younger members of our profession will have every opportunity of participating.

The advent of electric traction has, of recent years, altered all our pre-conceived ideas of railway and tramway development, and has rendered the construction of underground and overhead railways possible on a scale hitherto unprecedented, and although we cannot in the immediate future look to electrical traction superseding steam on long distance trunk lines, still for suburban passenger traffic we may expect its adoption. This I will allude to later on.

A highly interesting mountain rack railway, operated by three-phase current, is the Jungfrau Railway, which starts at the "Kleine Scheidegg," situated 2,064 metres above sea level. It is chiefly in tunnel, reaching an altitude of 4,093 metres. At the end of the railway journey passengers will be elevated a distance of 73 metres by a lift to the summit of the mountain, 4,166 metres above sea level. The gradient will be 25 per cent. There are to be branches to the main tunnel at intermediate stations, terminating in the open, so as to give passengers an opportunity to view the scenery.

The Manchester and Liverpool Express Railway.—The work of construction of this railway, which was authorised

by Parliament in 1901, is about to be commenced, and, as you are doubtless aware, it is on the "monorail" system, with which the name of Mr. Behr is associated, although, it appears, he makes no claim to be the originator of the principle, as many engineers, since the time of Telford, have brought forward different forms of the monorail. The high speed attainable on this system will, it is expected, meet the difficulty of great acceleration on the ordinary railways, where "mixed speeds" exist. The first practical adaptation of this system was the construction, in 1887–8, of the mono-railway between Listowel and Ballybunion, in Co. Kerry. The total length of the proposed line is 34½ miles of double track, and this distance will, it is stated, be accomplished, without stoppage, in 20 minutes, or at the rate of 110 miles an hour. The permanent way will be supported on a trestle-like structure, in the form of the letter **A,** and five rails will be used in connection with the system—the main "monorail" and four guide rails, two of which will lie longitudinally on each side of the row of trestles. There will be an elaborate system of signalling, almost entirely automatic, and there will never be more than two carriages on the whole line at a time. The carriages will have four continuous-current motors, having a normal capacity of 160 h.-p. at 720 revolutions per minute. The motors will be fixed low down to keep the centre of gravity of the carriage low, each motor weighing 2¼ tons.

Whether this railway will prove a commerical success is a matter on which there is a diversity of opinion. In any case, great credit is due to Mr. Behr for his untiring energy in introducing the principle for the service of the public.

Our own country has not been backward in railway enterprise, as within the past few years we have witnessed the absorption by the G. S. & W. Ry. of the W. L. & W. Ry., and other smaller companies in the South of Ireland, whether

for good or ill remains to be proved ; the long talked of connection from Rosslare to Waterford, opening up a new route, *via* Fishguard (on the Welsh Coast), with the South of England, is well under way, which enterprise will entail extensive harbour construction at Rosslare and Fishguard ; the extension of the D. W. & W. Ry. from New Ross to Waterford, with running powers to Cork and Limerick ; the acquisition of the B. & N. Counties Ry. by the Midland Railway of England opening another new route to the North of England ; and the extension of the light railway systems in Donegal, are among the most notable.

Light Railways.—No absolute and accepted definition of a light railway has yet been propounded ; the meaning of the expression is included in expression " tramway " under the Tramways Act of 1883. There are, however, certain sections in the Regulations of Railways Act, 1868, which describe the expression " light railways " as used in sec. 23 of the Tramways Act, 1883, which regulations, amongst others, stipulate that the weight of locomotive engines and vehicles shall not be greater than eight tons on any one pair of wheels, and that the rate of speed shall not exceed 25 miles per hour, which simply means that it is a railway lighter in labour, cost, and mode of construction than the ordinary railway ; and with this description—not definition—we must rest satisfied, as it seems as difficult a term for our legislators to define as the expression " fair rent."

Previous to the Light Railways Act of 1896, Ireland had been the recipient of legislation in connection with so-called light railways or tramways, of which some 600 miles were constructed and promoted under the provisions of the Acts of 1860 and 1883 ; the lines promoted prior to the latter Act were dependent on baronial guarantees alone without any State aid. Those promoted under the Act of 1883 were also guaranteed by the baronies up to 4 and 5 per cent. of the paid-

up capital ; the Treasury were authorised to return half of this sum, such half not to exceed 2 per cent. upon the paid-up capital of the company, or to a sum in the aggregate not exceeding £40,000 per annum. The capital for some 300 miles of light railway or road railway, chiefly of narrow gauge, was, with difficulty, found by the promoters, and the lines constructed at a cost ranging from £3,000 to £4,000 a mile for narrow gauge road railways. Had, however, the Treasury guaranteed the half of the capital up to the 2 per cent. in the first instance, the lines could have been financed without difficulty at a low rate of interest, thereby effecting an enormous saving to the guaranteeing areas, and many more of these useful lines might have been constructed.

These lines, however, although not paying a dividend directly, are of great advantage to the districts they traverse, and tend towards the improvement of the condition of the people—fishing industry has been developed, produce and live stock have found better markets, and wild and romantic scenery has been rendered easy and comfortably accessible to the tourist, for whom also big hotels have been built.

As a further example of the urgent need for light railways, and also of the benefits they confer, I will cite the case of the Galway quarries. Some years ago it took six weeks to transfer a block of green marble from the quarries near Recess, in Galway county, to the nearest shipping port. Now it can be done in as many hours by the railway recently constructed under Mr. Balfour's Act. This quarry is worked by an American company, and large quantities are shipped to the States.

By Mr. Balfour's Act of 1889, whereby State aid was made contingent upon an existing railway company constructing and working the new line, some fifteen lines were constructed, chiefly on the Standard Irish Gauge, totalling about 310 miles, the Government contribution, or free grant, being over

one million. Most of the lines constructed under this Act cost £6,000 to £10,000 a mile.

In 1896 another Light Railways Act was passed contemporaneous with the English Light Railways Act of the same year. Under this latter Act it appears from the official reports that the applications for light railways in England amounted to nearly 1,000 miles of line, estimated at a cost of £6,800,000. Although it could not be expected that similar results could be attained in an agricultural country like Ireland, still the result is significant.

By the Irish Act, which was described as an Act to facilitate the construction of railways, &c., &c., a sum of £500,000 was advanced by the Treasury as a free grant, and this sum has been allocated chiefly to one county only (Co. Donegal), and to one railway company (the Lough Swilly Railway Co.) for two lines of railway, the works on which were only commenced in 1898, after a lapse of two years from passing of the Act, and one of the lines is not yet completed. However, be the cause of this as it may, the Railways (Ireland) Act, 1896, instead of facilitating the construction of railways (or tramways), seems to have had the opposite result—the reasons being the restrictions in the Act whereby the Treasury are to be satisfied that a railway company existing at the time will construct, work, and maintain the proposed railway, thereby shutting out all private enterprise, the consequence of this limitation being that no applications can be made under this Act by any individual, corporation, or company (as is authorised under the English Act, with the astounding result before mentioned), except by an existing railway company, thereby driving promoters back on the Tramways (Ireland) Act of 1860, with its costly and cumbersome procedure and restrictive clauses. Again, although this Irish Act of 1896 does not specifically state that railways promoted under the Act shall be confined to

congested districts, still it has been so administered and con-
fined to those districts which have no individual resources,
although the Act specifies in words that the proposed railway
should be " necessary for the development of the resources
of any district."

Had the same facilities been given to Ireland as to England,
Wales, and Scotland, under their Act, doubtless several
useful projects to develop the real industrial resources of
the country would have been undertaken by private enter-
prise, such as the opening up of the Leinster and other coal
fields, granite, marble, and other quarries, &c., &c., but which
still lie dormant. It is to be hoped that if any future
legislation is effected in this direction the defects above
enumerated will be remedied, and that some comprehensive
Act embracing also the canals and navigable rivers of Ireland,
so as to give every facility for developing the industries,
mineral and other, resources of the country will not be lost
sight of by our legislàtors.

Light railway enterprise is also somewhat hampered by
the onerous regulations of the Board of Trade, especially as
regards costly signalling, as compared with the United
States, where, for instance, on the run from Buffalo to
Jersey City (447 miles) there are no signal cabins, the whole
block system being automatically worked. The system is
quite safe, and is spreading all over the States.

Boston station, with 775 trains in and the same number
out each day, is worked by one signal cabin with seven men,
by means of the pneumatic system, and which has been
recently adopted in England on the N. E. Railway at Tyne
Dock.

Tunnelling has lately grown to be a very prominent branch
of engineering. Civilisation is demanding mountain ranges
to be more frequently pierced, rivers, ocean channels, and
bays to be crossed beneath their bed, and cities to be honey-

combed beneath their surface. One of the largest works of
this class, nearly completed, is the Simplon tunnel between
Switzerland and Italy. Progress is reported to be 5,400
metres on the Italian side and 7,880 metres on the Swiss side.
Numerous streams of water have been met, varying in
quantity up to 4,800 gallons per minute, and part of the
tunnel is said to be costing 22,000 francs per metre.

The project of the great tunnel under the Irish Sea between
White Head in Co. Antrim and the] Mull of Cantyre, is
still in *statu quo*, although present indications make it appear
that it will be kept before the public by the enterprising
Irish engineer who has conceived it, and although we cannot
expect the consummation of the project in our day, still if
ever the fact is accomplished let us hope it will tend to unite
in more senses than one the two kingdoms for the benefit
of those who come after us.

The Greathead Shield process of tunnelling with which
you are doubtless familiar has revolutionised the art of tunnel
construction, especially in porous soils, and it is in the London
tube railway projects we see the greatest advancement in
this direction.

Water Supply.—The most extensive works for water supply
now being carried out are those to furnish the city of
Manchester with water from Thirlmere Lake, into which
will be diverted the waters from a total catchment area of
11,000 acres, and when impounded by the dam will have
a surface area of 793 acres and a capacity of 8,130,686,693
gallons.

The aqueduct is 96 miles, of which 51 miles is in tunnel
cut and cover, and 45 miles of cast-iron pipes (40 inches
diameter). The total length of the dam is 880 feet; the
maximum depth, 60 feet. The dam is constructed of 5 to 1
concrete, with large blocks of rock embedded, and it is faced
with masonry.

The total cost of the undertaking will be, when completed, £4,400,000.

Mention may also be made of the Coolgardie pipe line, which is unquestionably one of the most interesting undertakings now under construction. Starting from a reservoir about 35 miles from the coast line of Western Australia, it runs about 328 miles to the Coolgardie gold fields. It is 30 inches in diameter, and both the round and longitudinal seams have a special form of joint doing away with riveting.

The largest water supply in Ireland, and perhaps one of the largest in Great Britain, is the Mourne Extension Scheme of the Belfast Water Works, now under construction, powers for which were first obtained from Parliament in 1893. A peculiar feature in this Act is that the onerous condition embodied in all the English and Scotch Acts of giving what is called the Miller's third, or a third of all the water in a regular daily flow, by way of compensation, is absent from the Belfast Water Act of 1893.

The catchment areas form the gathering ground of the Kilkeel and Annalong River, the highest part of which has an elevation of 2,800 feet over sea level, and the area some 9,000 acres, so that the chances of pollution may be taken as non-existent. They will afford a maximum supply of 30 million gallons a day. This supply is to be conveyed by aqueducts, portion of which is in tunnel and also by metal pipes. Two large storage reservoirs have been authorised. The largest will be located in the Silent Valley, and about 200 acres will represent the top water surface, with a storage capacity of 2,500 million gallons. The embankment will be of earthen and puddle construction, and 93 feet high. The second reservoir will be situated in the Annalong Valley, the storage being 1,250 million gallons, also with an earthen embankment 100 feet high.

The length of the aqueduct is about 35 miles. Tunnels,

some 7 miles in length, have been driven through mountains,
and valleys crossed by means of dips formed of steel and cast
iron pipes.

The capacity of the service reservoir at Knockbrickan
will be 100 million gallons. From this to Belfast the con-
nection is by pipes, portion of which in deep cutting is laid
double in mild steel pipes to reduce to a minimum the likeli-
hood of repair.

The total outlay for works is estimated to be £1,250,000.

Water Power.—The development of the use of water-
power in the industries has within recent years made great
strides. The projects for the utilisation of water power,
carried out and in contemplation, are too numerous to
mention in an address of this kind ; suffice it to say that
one of the largest water-power plant yet undertaken is
that of the St. Lawrence Power Company of Massena, N.Y.
There most expensive works have been built for an ulti-
mate capacity of 150,000 horse-power, although the present
capacity of the generating station is but 35,000 horse-
power. The tunnel of the famous Niagara Falls plant limits
capacity of that plant to 100,000 horse-power. In our own
country the water-power available is in a great many cases
intermittent. The vested interests also of riparian owners,
fisheries, navigation, &c., which do not prevail in other
countries, have had a deterrent effect ; and although the
Shannon Power Scheme has received Parliamentary powers,
there seems no indication of the capital being forthcoming
for the enterprise.

As regards steam-power plant, that of the Third Avenue
Railroad Power Station in New York, which is now in course
of construction, will have a capacity of 72,000 horse-power
at the rated capacity of the plant, but can furnish 100,000
horse-power if necessary.

Canals.—Within the last year the Panama Canal project

has been taken up by the United States Government on the recommendation of a Commission appointed for the purpose of reporting on the respective advantages of the Isthmian and Panama Canal.

The Chicago Drainage Canal is another vast work of much interest. It will connect the watershed of the Chicago Basin, which slopes into Lake Michigan, with that of the Desplaines and Illinois Valleys, which slope towards the Mississippi River. The volume of material excavated was about 40 million cubic yards, and 388,405 cubic yards of masonry were built in retaining walls. The total tost, including the diversion of the Desplaines River, up to 1901, was about £7,000,000.

Other recent important works are the Dortmund Canal and Erie Canal, and the improvements effected in the Sulina branch and outlet of the Danube.

In the United Kingdom canal construction has been at a standstill of late years. But recently there has been a demand for cheap carriage to enable the manufacturer and agriculturist to compete with the foreigner ; this, as far as our own country is concerned, demands the attention of the Government, which should encourage extension and organisation of our splendid system of waterways. In this connection due credit must be given to the energetic and enterprising Member for the St. Stephen's Green Division of the City of Dublin for the part he is taking in bringing about this much-desired result.

Mr. Hawkshaw stated in his recent Address that a ton of goods can be carried from Hamburg to Berlin—174 miles—for 4s., and for the same amount from Buffalo to New York, a distance of 500 miles, and that one of the English south county railways would charge 7s. 4d. for carrying a ton of firewood 47 miles.

The extension of our Grand Canal system, from Athlone to Galway, for instance, would give a magnificent system of water

transit between the east and west coasts, and as it connects with the Shannon navigation at Athlone, which extends from Carrick-on-Shannon in the north to Limerick in the south, the whole of the centre of Ireland would be in direct water communication with the seaports in the east, south, and west.

In fact, if our Government would follow the lead of France, where inland navigation is fostered by the State, and even give over the Shannon navigation (which is owned by the Government) to the country, it would go a long way in solving the transport difficulty—in fact, I would advocate State purchase and acquisition of the existing canals and river navigation of the country, in the first instance, and the State purchase of the railway system could follow after.

Haulage.—The most efficient means of dealing with haulage by mechanical means has been exercising the minds of engineers of late, and at several Navigation Congresses held within recent years the question of mechanical haulage has been the subject-matter of various papers, some advocating one system, some another ; but what system would best suit the canals and navigable rivers in Ireland would, of course, depend on the physical conditions in each case. Generally speaking, the success attained on the Continental waterways, of the electric locomotive, and the running rope along the tow-path, would point to some such system being suitable for our water-ways.

Mention may here be made of the projected canal from the Medway to the Thames, saving a round of many miles about the treacherous coast of Kent for the barges which ply between these places.

In connection with drainage, perhaps the most important and extensive work is that of the Valley of Mexico, which has been proposed by one scheme or another for three centuries. The work was commenced in 1807, but it was not until 1900 that the main drainage works were opened.

In Ireland arterial drainage has been at a standstill for many years, owing to the unsatisfactory system of land legislation prevailing. This question merits the attention of the Government when dealing with legislation for the material development of the country.

As regards sewage disposal, the Mersey and Irwell improvements are amongst the most interesting recent undertakings of the municipal engineer. Ten years ago these streams were practically open sewers, so offensive that a commission was appointed, with power to compel the purification of sewage before it enters the streams, whether it comes from streams or industrial establishments; and the Manchester sewage disposal experiments were the first investigations of biological methods of disposal to be undertaken on a large scale, and led to the recommendation of open septic tanks and raised filters for the entire sewage of the city, which was adopted with most satisfactory results.

Electricity, which now occupies a most prominent place among the branches of practical engineering, is constantly startling the world by some new adaptation of its powers.

Electric traction has until quite recently been confined to tramways, tube, and overhead railways in cities; now it is contemplated to use it to supersede steam on our main lines of railway. No doubt this is feasible; but the question is, would it pay? As regards suburban railways, which deal with passenger traffic almost exclusively electrical traction would seem to be imperative for their existence. Already the Lancashire and Yorkshire Ry. Co. are about to adopt it on their line to Southport; the London and Brighton also have it in contemplation, to meet competition with projected monorail lines.

In Italy the Adriatic and Mediterranean Ry. Cos. work their passenger traffic for distances of 18 and 30 miles, respectively, into Madrid by electric traction, without suspending their ordinary through traffic by steam.

The Great Western Railway of England are adapting their Hammersmith Cross-City Railway for working by electric power; and Mr. Pember, K.C., is reported to have stated in the case of the London and S. W. Tramways that the railway had lost £10,000 a year by the opening of electric tramways in London and its suburbs.

It is stated that railways in Connecticut, originally worked by steam, running four trains a day at a loss are now, after electrification, running fourteen cars a day at a profit, and that this result has decided the North Eastern Railway Co. to electrify their local lines, although they have to protect the third rail, which the American companies have not to do. I believe in future all local lines in all parts of the country where competition with tramways exists will have to depend upon electrification for their continued existence.

Wireless Telegraphy.—The problem to be solved is thus stated by M. Victor Thiran :—To send through space by means of a small transmitter, signals that can be received at the greatest possible distance, by suitable apparatus, without the sending and receiving stations being connected in any manner. Since the memorable researches of Professor James Clerk Maxwell, in the early sixties, many experimenters have attained success in this direction ; but it must be admitted that, in bringing " wireless " telegraphy into practical use, Mr. Marconi has taken a leading part. His experiments also tend to prove he is very near solving the problem of synchronisation. By electrically " tuning " his instruments so that the latter can only be influenced by waves of determined length, and *solely* by them, he has succeeded in operating ten transmitters connected with one and the same antennæ, each sending its message to one only of ten receptors placed side by side, and also using a single receiving antenna.

The progress made since the first practical attempts at

wireless telegraphy in 1897 has been enormous, and it seems probable that electric waves, before long, will form an invisible network of vibrations round the world.

Private Bill Legislation.—During the past Session the following resolution, was proposed by your President :—

" That this meeting of the Council of the Institution of
" Civil Engineers of Ireland is strongly of opinion that
" legislation for Ireland providing for the reform of
" Private Bill procedure on the lines of the Private Bill
" Procedure (Scotland) Act, is urgently required ; that the
" existing system is dilatory, extravagant, and prohibitive
" of enterprise in Ireland, and imposes an undue burden on
" both promoters and opponents of private bills ; and that
" this Council calls upon the Government to take steps to
" further legislation for the purpose of bringing about this
" much-required reform."

A Committee of this Institution was appointed to report on the subject, and the matter is still under consideration by them. The question has been ably dealt with both in the Press and on the public platform within the past few years, but the Government have as yet taken no steps to bring about this much-needed reform. However, since Lord Dudley has been in office, we notice with pleasure his appreciation of the inconvenience and expense in which Ireland is involved by the present system. Vast sums of money have been lost to the country, and wasted on extravagant litigation in London, which would have been retained had a proper tribunal been created to deal with the procedure in a simpler and cheaper manner.' The opponents of reform have always suggested the difficulty of obtaining a good and workable tribunal ; but they have got over that difficulty in Scotland, and the system appears to have given the greatest satisfaction during the short time it has been in operation. Of course, in every new system there are some improvements, which

practice shows might be effected, but they do not interfere
with the ultimate satisfactory working of the system.

Municipal Trading.—The question of municipal trading
is now occupying public attention, in consequence of the
rapid increase in the rates. The public are at last beginning
to see that the dangerous policy of municipal bodies pro-
moting intricate business ventures with the public funds
is not the El Dorado they were led to expect, which fact the
people in the United States learnt over fifty years ago by
the bitter experience of financial disaster and destruction
of State and local credit resulting from this policy. I cannot
do better than quote the *London Times* on the subject, which
says :—" The time has come for the mass of the people to
make up their minds about a movement which must have
consequences reaching far beyond the expectations of those
who now encourage or acquiesce it. Nor is it an answer to
say, ' we will stop when mischief is being done.' Once create
large municipal staffs ; once bring together large bodies of
men accustomed to light work, regular employment, and good
wages ; put down plant, erect buildings, and purchase land ;
create vested interests with subtle ramifications, and it will
not be possible, without using heroic means, to rectify a
series of mistakes. Then, too, there is the question of the
capacity of our public bodies to deal effectively and wisely
with all the functions thrust upon them. And, gravest
uncertainty of all, there is the question whether the purity—
such as it is—of municipal government will be maintained
if it exercises a multitude of duties, touches finance at many
points, and makes politics and business almost synonymous."

From what I have said you will no doubt admit the highly
important part which our Institution plays, not alone in
supporting and aiding our Profession and its members, but
in the development of the various branches of science with
which we have to do. I need hardly point out to you that

it is a paramount duty for each and every one of us to give it every support by contributing papers for discussion and by donations to the Library.

The success and status of the Institution in a great measure regulates the success and status of its members. Such being the case, I feel certain of your cordial support in every measure which will tend to achieve these ends.

MR. B. W. WISE moved that the best thanks of the members be tendered to the President for the very interesting Address he had presented to them.

He had come from the "cold North," and was glad to be able to tell them that the President was becoming well known in Belfast.

He considered their choice as President could not have fallen on a better representative of the profession.

He did not know whether he was right in taking that opportunity in saying that he wished they could see the Institution of Civil Engineers in Belfast, if only once in a lifetime. He thought it would do a great deal of good if the Institution were to hold a summer meeting in Belfast. It would bring prominently before the professional gentlemen in the North the fact that there is such an important and flourishing Institution.

MR. J. P. GRIFFITH said it gave him great pleasure to join with Mr. Wise in moving the vote of thanks to the President. They were old colleagues and were in college together, and he was very pleased to listen to his very able Address.

The PRESIDENT thanked the members for the very kind reception they had given his Address, also for the very kind words which had been said by Mr. Wise and Mr. Griffith. He trusted they would excuse him making any extended reply as he had already spoken for such a long time.

MR. JOHN H. RYAN, President, in the Chair.

The following resolution, sent forward by the Council for ratification, was passed unanimously :—

The PRESIDENT, at the Annual Dinner of the Institution of Civil Engineers of Ireland, held in their Hall, 35 Dawson-street, on the 17th December, 1902, when proposing the health of His Excellency the Lord Lieutenant of Ireland, who honoured the Institution by his presence, suggested to His Excellency that he should honour the Institution by allowing them to elect him an Honorary Member, which suggestion His Excellency was pleased to accept—

RESOLVED—"That we, the Members of Council, now unanimously adopt the suggestion of our President, and elect the Right Honourable William Humble Earl of Dudley, Lord Lieutenant-General and General Governor of Ireland, an Honorary Member of the Institution of Civil Engineers of Ireland."

The following candidates were balloted for and duly elected :—

MICHAEL THOMAS MORLEY ORMSBY and THOMAS ATOCK, as Members ; FRANK ALEX. SOMERVILLE CARNEGIE and JOHN JOSEPH FLEMING, as Associate Members ; J. E. PALMER and ALFRED M. CORNWALL, as Associates.

ELECTRICAL TRANSMISSION AND TRANSFORMATION OF ENERGY.

By MARK RUDDLE, Member.

THE economical transmission of energy and its conversion into useful work is one of the fundamental problems of engineering, second only to its primary transformation into

a live or useful state from the elementary conditions of coal and water. Until a very recent period this transmission and conversion has been almost entirely effected by varied and ingenious mechanical methods, with which we are all so familiar that it is unnecessary for me to dwell upon the matter. Recently, however, a rival has sprung up which has proved so versatile in adaptability and so efficient in practice that it has secured an important place in the engineering world, and bids fair to oust its older competitor from a large section of its hitherto undisputed field of work, for the transmission of energy by electrical means aggregates to-day over a million h.-p. in all parts of the world, and for almost every purpose for which it is required in lighting, heating, motive power, and chemical industries. This rapid development is in great part due to the demand for increased and more economical production in all branches of manufacturing industry necessitated by the keen competition in trade, and the importance of fulfilling orders promptly.

I purpose to-night to deal only with one section—namely, its application to motive power in workshops and factories, and to bring before you as concisely as possible the reasons for its success and rapid adoption.

I desire at the outset to disclaim any intention to suggest that electrical energy generated by steam or water is cheaper *at the generator* than steam or water power itself, and I find it necessary to do this because the publication of the savings which have been effected in various places by the change from mechanical to electrical driving has, perhaps not unnaturally, caused a certain section of the public to conclude that the mere substitution of an electric motor for a steam or gas engine, as a prime mover, will result in extraordinary economies. Undoubtedly, in the case of small powers, a considerable saving is effected in many instances by the substitution of an economical electric motor for an inefficient

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and troublesome steam or gas engine, especially if the former
be connected to a public supply; but the main economy
obtained in converting a factory from mechanical to electrical
driving is in the transmission from the prime mover to the
various machines and tools distributed about the premises,
and its direct application on the spot to the work to be done.

In a mechanically-driven factory or workshop the most
striking feature on entrance is the complicated mass of over-
head shafting and belting employed to transmit the power,
and the obstruction to general supervision and effective
lighting caused thereby, to say nothing of the free distri-
bution of dust and dirt by the rapidly-moving belts over
materials and bearing surfaces.   This, however, is not
the most serious drawback, although the most noticeable;
the real money-waster is the heavy and continual loss of
energy necessitated by having to keep the transmission
system in constant motion, amounting, in many cases, to as
much as from 40 % to 70 % of the total power generated by the
prime mover, and this loss continues whether individual
machines are at work or idle, since the shafting must be
kept running in readiness for use at any moment. When,
on the contrary, the electrical method of transmission is
used, all this mass of shafting and belting is replaced by a
few motionless cables, which may be laid out of sight under-
neath the floor, and tapped off as required to feed the indivi-
dual motors directly attached to the majority of the machines
and tools, with only an occasional length of light shafting
where it may be found convenient to group several small
machines driven by one motor. By thus getting the energy
delivered right up to the tool itself without any unnecessary
losses on the way in overcoming the friction of moving
shafting, &c., the highest percentage of economy can be
secured commercially over every method of transmission.

Even in the most efficient cases of mechanical transmission,

as first laid down, there comes a time, as the business develops, when the inelasticity of the mechanical drive becomes a serious drawback. Machine after machine is gradually added to meet special classes of work, and the complication of added shafting, often compelled to drive heavier types of tools than those installed in the older parts of the works, throws such a strain on the bearings, hangers, &c., of the original drive that it becomes a wonder how it stands at all, and certainly entails a heavy frictional loss in transmission.

With electrical driving you have a perfectly elastic system ; new motors can be added as required without in any way affecting the efficiency of the original installation, fresh tools can be placed in positions which would be impossible if driven by lines of shafting and belting, and the machines can be removed and placed in other positions, if at any time it should be found desirable to do so, with the minimum of expense, as the running of an additional length of cable is all that is required to connect up the motor to the nearest distributing main.

In the case of new factories and works, some very important advantages are gained by adopting electrical driving, it not being necessary to have such heavily constructed walls, floors, and roof framing as is compulsory for shafting transmission. The various shops and departments may be arranged in the best way for consecutive handling of the work in its various stages of manufacture, and irrespective of the position of the prime mover ; detached buildings for special classes of work may be driven with the greatest economy, and the isolation of any specially dangerous sections of the processes may be arranged to meet insurance requirements with the greatest facility. There is no necessity at the start of a business to lock up a large amount of capital in the transmission arrangements in order to provide for possible future extensions, as these need only be made when actually required,

and without fear of overloading or interfering with the existing conditions or the progress of work in hand. Temporary extensions may be made without delay to meet special cases or to deal with detached work, as the cables can be quickly run to the spot, and as quickly removed when they have served their purpose, and are then available for use elsewhere, at the minimum of expense for shifting.

Some other advantages of electrical driving, common to both new and existing factories, are the complete control which is available over the speed of individual tools, insuring that each may be worked at its fullest economical output, and not be dependent on the speed of the line-shafting, as in the old way ; the independence of each separately driven tool from being affected by the breakdown of any other unit, and the dispensing with the frequent belt-tightening, which causes serious delay if it should happen to be the main belt, or one driving a long line of shafting ; the greatly lessened cost of maintenance, as the electric cables are motionless and require no attention ; the motors have few parts requiring renewal, and these quite inexpensive, their friction loss does not increase in time and unnoticed, for they are either in full working order or they are broken down ; there is no intermediate stage.

Portable tools can be operated with the greatest facility in any position, and where work is too heavy or unwieldy to bring to the tool the latter can be shifted to the work, and, if necessary, several tools can be operated at once on the same piece of work, thus saving much valuable time. This latter feature is of the greatest importance in the manufacture of electrical plant, where fly-wheels and armature castings, often 30 ft. to 40 ft. in diameter, are effectually planed, drilled, and slotted by small tools temporarily placed in position, rendering it unnecessary to have special boring lathes for this purpose, and saving the carrying of the work to such

if they had been available. In combination with flexible shafts electric motors are specially useful, as they can be slung up, and the tool on the end of the flexible shaft can be operated with facility to execute work in the most awkward positions.

Auxiliary plant, such as ventilating fans, blowers, pumps, &c., in out-of-the-way positions, can be operated with the certainty that frictional losses are at the minimum.

The electrical driving of cranes, whether travelling or radial, shows great advantages over mechanical driving, or with separate steam engine, not only in the economy of the motive power, but in the increased speed with which the loads can be lifted and traversed—a most important matter in getting full work out of machine tools, and minimising unproductive capital in plant.

A secondary advantage of electric driving is the ease and accuracy with which the energy absorbed by any machine or tool can be ascertained, and a check kept upon its working condition at all times. This is a matter of extreme difficulty and expense if attempted in ordinary shafting transmission, but is valuable in checking the estimate of the tool-maker as to the power required to drive it, and which is usually much understated. It also enables the cost of driving to be properly apportioned to each machine, as well as indicating where efficiencies may be improved.

As an instance of this I may mention some very interesting tests made by Mr. Langdon of the Midland Railway at their Derby Works, of the comparative costs of running with electric motor driven shafting, and of gearing the electric motor direct to a lathe, the lathe in both cases being set to make three cuts simultaneously, and under the same conditions. When the lathe was driven from counter-shafting the power absorbed was 1,188 watts ; weight of metal removed, 9·75 ozs. ; time occupied. 2·95 minutes ; or an average of 275 watts per oz. of metal per minute. When the lathe was

driven by the motor geared direct the power absorbed was
616 watts; weight of metal removed, 9·75 ozs.; time occupied,
2·25 minutes; or an average of 143 watts per oz. of metal
per minute.

It may, perhaps, be suggested, granting the increased
economy in transmission, and all the other advantages claimed,
will not the initial cost of the plant and the increased cost
of the energy at the prime mover offset all these advantages;
in other words, will it pay?

Of course, every case must be considered with regard to
its particular circumstances, but, speaking generally, the
initial outlay in a new works will not exceed a first-class
equipment of shafting, &c., for mechanical driving, and in
some instances will be 50% less. The cost of energy at the
prime mover will, however, be much less, as the total horse-
power required to be generated is reduced in consequence of
the increased efficiency of electrical driving. For instance,
in arriving at the total amount of electrical energy required
for replacing mechanical driving in a certain factory, careful
tests were made of the total h.-p. generated, and it was found
to average 260 h.-p. under regular working conditions,
and when the machinery was not in use the transmission
alone was found to absorb 160 h.-p. When converted to
electrical driving it only took 160 h.-p. to drive the whole
plant, and when everything was turned off there was only
the friction of engine and dynamo running light. It would,
of course, be misleading to take the indicated h.-p. of the
engine, and allowing 1⅓ h.-p. to be equal to a Board of
Trade unit, to multiply this by the working hours per annum,
and take the product as representing the number of units
required, because the individual machines of any factory are
never at full work all the time, and it is here that the great
saving comes in, for while a machine is at work it can only
absorb electrical energy in exact proportion to the work it

is doing, and when not at work no energy at all is consumed
or wasted. The all-day efficiency is enormously increased,
amounting in some cases to as much as 50% of the maximum
power installed, which would otherwise be wasted in running
the shafting, the bulk of the latter's losses being constant
at all loads, and therefore specially expensive when parts of
the system are underloaded. It is this absolute saving which
enables electrical energy to be used with economy in factories
and workshops in spite of an apparently greater cost for
generation by steam dynamos.

A very striking instance has recently been published of
the saving effected in the works of Siemens Bros., at Woolwich,
where 1,200 h.-p. of electrical driving has replaced mechanical
transmission, the result being that 3,000 tons of coal were
saved annually, and the wages of 6 drivers and stokers.

In the case of a Lancashire machine works, which takes
its electrical power from a public supply, the yearly cost for
a maximum demand of 330 h.-p. works out at £2 12s. per
h.-p., as against the annual cost for a separate steam plant,
which in Lancashire is averaged at £5 per h.-p.

In deciding to adopt electrical driving it is necessary to
carefully consider the equipment from the point of most
economical production. Every manufacturing industry has
its own special requirements, though these have frequently
to take second place where a rigid mechanical transmission
is in use. The arrangement and grouping of the shops or
departments must be studied, the types and sizes of the
different tools, the variety of the speeds, and the nature of
the work expected. The speeds of the motors should be
fixed for the most economical maximum output of the tools,
and where the range of speeds or the nature of the work
requires the use of change-gear on the machine the motor
should always gear down rather than up. An advantage
of using such ordinary gearing is that any similar motor may

be mounted on the machine in case of breakdown of its own, owing to the absence of any special structural features, and that if a tool is out of work for any considerable time, the motor may be used to operate a temporary tool elsewhere. Of course the ideal method is to have the armature of the motor mounted directly on the main spindle of the machine itself, and thus directly applying the power to the tool. The speed control and the output are then independent of any other machine, and no longer subject to the speed of the line shafting. This is specially valuable in the case of shears, punches, and similar tools, which are only in operation at intervals.

It is generally considered that for machines above 2 or 3 h.-p. it pays to use separate motors. When using a few large motors to drive independent sections of shafting it is necessary to group the machines so that those of similar type, speed, and power are, as far as possible, on the one shaft and in fairly constant use. This method is frequently adopted when changing over an existing shop to electric driving, but, of course, all extensions could be made with independent motors. The starting and regulating switches can easily be placed in the most convenient position for the workman, but it is advisable to have the fuses or cut-outs in locked cases, so that the over-load capacity of the motors may not be exceeded.

From some tests made in the workshops of the Vienna. Warsaw Railway, as to the relative efficiencies of group and independent driving of lathes, it was found that independent driving required but 69 % of the power necessary for group driving when all the machines were at full work, and the efficiency was still further increased when some of the machines were at work for a portion only of the time. When, however, capital charges and general convenience were taken into consideration the all-round conclusion arrived at was

that independent driving was more advantageous when not more than 75 % of the machinery was operated continuously during the entire working day, and that when the plant was in continuous operation during the greater part of the time, group driving was, in many cases, found to be more advantageous.

Until a comparatively recent period electrical driving was generally carried out by means of direct current motors, owing to the difficulty of obtaining commercially useful alternating ones ; but within the last four years the design and manufacture of polyphase motors has been so materially improved that the majority of all recent electrically driven factories and workshops have been equipped with three-phase motors, and, in every case, with entire success. Indeed the advantages of the latter system in reliability and low up-keep have in several instances caused the users of direct current motors to gradually discard this type and to refit their works with three-phase plant.

The extensive works of the Shuckert Co., of Nuremburg, employing some 10,000 hands, and the Russian Government Dockyards at Odessa are striking instances of this.

A special feature of the three-phase system is that if the driven machine should get jammed from any cause, and the motor pulled up, no damage results to the motor ; whereas a direct-current motor would be seriously injured, if not burnt out.

Some instances of large three-phase motors in use for heavy work are to be found in the new iron and steel works at Hoboken, near Antwerp, where motors of 350 h.-p. are directly coupled to the mills for rolling heavy plates. The total h.-p. of motors in use there is 1,500, and the works when completed are estimated to require 30,000 h.-p.

The improvement of the design of single-phase alternating current motors has not, however, been neglected, and they

are now coming into satisfactory use in places where three-phase supply is not available.   Some of the more recent installations have been made at Hammersmith, where condensing water is being pumped from the Thames by two single-phase motors of 27 B.H.-P., coupled direct to 8″ centrifugal pumps, lifting 60,000 galls. per hour against a head of 45 ft.   These motors have stood an overload of 70 % for a considerable time without heating, and start under load without difficulty, their efficiency being 82·5 %.

At the same place there is an overhead travelling crane, driven by a 20 B.H.-P. single-phase motor, lifting five tons at 16 ft. radius, or one ton at 42 ft. radius.   The lifting speed is 80 ft. per minute, and the crane travels at 150 ft. per minute.   The jib is 48 ft. long, and the crane balanced to support two tons at 45 ft. radius.   There are independent motions for hoisting, revolving, jib-adjusting, and propelling, all driven from the same motor, and it is possible to perform all four operations at the same time, although it is not usual to perform more than two at a time, owing to the great length of the jib, and the limited operating space.   The motor is a standard 50 cycle one, and is supplied at a pressure of 405 volts.   The current is collected from an insulated third-rail (the gantry rails acting as a return) by a special brush connected to slip rings at the centre of the crab, so that the crane can be revolved indefinitely in either direction.   The connection between the motor and the first-motion shaft is by a steel worm gearing into a gun-metal wheel, running in an oil-bath ; a friction clutch is interposed, but has been found unnecessary, as the motor will start the first-motion shaft in either direction without it, and without exceeding full-load current by more than 25 % for the momentary period while accelerating.   The controller starts the motor in either direction by turning a single handle, right or left, as required.

It is difficult to obtain from manufacturing firms reliable statistics of the exact saving which has been obtained by the substitution of electric for mechanical driving, but some instances have been published in various technical transactions which are, I think, sufficiently interesting to be quoted.

The Westinghouse Air-brake Co. of Pennsylvania had originally some 30 steam engines in use, supplied from a grouped set of boilers aggregating 1,400 h.-p. These scattered engines were replaced by three-phase generators, coupled to steam turbines, the shafting was divided up into convenient short lengths, each motor driven, and some of the tools independently driven by separate motors, a total of 57 motors, aggregating 1,065 h.-p being installed. When finally converted, a lengthy serie of tests showed a reduction in steam consumption of 40%.

Another instance is the extensive works of Vickers, Sons & Maxim, at Barrow-in-Furness, where during three months working by steam-driven plant the average monthly consumption of coal was 476 tons, while in the following year when electric driving was installed the average monthly consumption during a corresponding period fell to 232 tons, notwithstanding that a number of new machines had been added, and the electric lighting of the works had been increased.

The Northumberland Shipbuilding Co. is probably one of the earliest examples of a shipyard entirely driven by electricity, using some 30 three-phase motors, varying from 5 to 50 h.-p., besides a number of three-phase winches, and taking their supply from the Newcastle Electric Supply Co.'s Station at Wallsend, which also operates a number of other shipyards and works on the Tyne of the aggregate amount of 3,000 E.H.-P.

At a meeting of the Franklin Institute in 1901 the Super-intendent of the Baldwin Locomotive Works, Philadelphia,

stated that his experience convinced him that to abandon electric driving in their works would entail an increased cost for labour of 20% to 25%, and 40% more floor space to maintain the same output.

Some interesting figures were given in a paper read before the Iron and Steel Institute at their meeting in Dusseldorf in 1902 as to the saving effected by electrically driven cranes in the Free Harbour at Hamburg. In 1901 the average working cost of steam cranes was 11s. 4d. per crane during 10 hours run, while the electrically driven cranes averaged 7s. for the same period ; the inclusive cost per ton of goods lifted being 2¾d. for the steam cranes and 1d. per ton for the electric cranes. The energy for the electrically driven cranes is taken from the town supply mains, the cost being 2d. per kilo-watt-hour.

Whether the supply of electrical energy for workshop purposes is to be by a generating plant in the works itself, or obtained from public supply mains, where such are available, is a matter to be determined for each individual case, and depends largely upon the price of the public supply, and whether it is desirable to sink additional capital in special generating plant. On general principles, where a number of works take their energy from a public supply, an initial advantage is gained by concentration of the generating plant, and a second and most important advantage is the improved load-factor secured by the combined supply to the various works. The average load of any workshop is rarely more than 35%, but the combination of a number of factories or shops with their varying demands must result, obviously, in a much higher average, and it is the economy effected by this higher load-factor which enables a public supply to be distributed at a low rate, with advantage to both supplier and consumer. Another point is that when a separate engine and dynamo is not used, the only shop losses are those in the

motors and distributing cables, and these vary in proportion to the work actually being done. In the case of overtime being necessary on certain machines owing to accumulation of work, or to a breakdown job having come in, it is certainly more economical to have the supply on tap, so to speak, than to have to keep the main engines, boilers, &c., at work for a small section of the shop, and in several works I am informed it is found more economical to run two shifts a day than to put in additional tools for special work; and this, of course, can be done with less expense from a public supply.

In connection with this there is a curious instance of a colliery at St. Helen's, Lancashire, which takes its electrical energy for coal-cutting, hauling, pumping, winding, and every other purpose from the town supply mains, effecting a saving of 80% in comparison with its former steam plant, thus showing that it pays to cart coal from the colliery and receive it back in the form of electrical energy, rather than to use it direct in its own steam plant.

When a factory is electrically driven it is only a step further to provide electric lighting when artificial illumination is required. This has an important bearing upon the economical operation of the works, as it is the only artificial illuminant which does not vitiate the atmosphere, and, consequently, cannot injuriously affect the health of the operatives in crowded shops, and when overtime has to be worked.

When a supply of alternating current is available its application to welding metals on a large or small scale is an easy matter, and of very great value in many workshops in which it is in daily practical use, the joints having 90 % of the original tensile strength. Some idea of the cost and convenience can be obtained from the following table of the plant capacity required, and the time of application :—

MATERIAL	E.H.-P.	TIME
$\frac{1}{4}$ in. wrought iron or steel	2·	10 seconds.
$\frac{1}{2}$ in. wrought iron or steel	6·5	20· ,,
1 in. round axle	25	45· ,.
1 in. square axle	30	48 ,,
2 in. round axle	75	95 ,,.
2 in. square axle	90·	100 ,,
1 in. Bessemer steel	22·5	64 ,,

Briefly summed up, the advantages of electric driving are—

1. Decreased loss in transmission from source of power to point of use, owing to the fact that the conducting cables are normally motionless, although they can be moved, bent round sharp corners, or shifted into any position while transmitting many horse-power without affecting their efficiency; they have little weight, and can be shifted or fixed with greater ease than any form of mechanical connection. Their safety is greater, as their use causes neither heat nor smell, and there is nothing to burst or give way.

2. The motors are efficient, and their speed under perfect control, either individually or collectively.

3. Tools or machines can practically be placed in any position, and shifted as required without disorganising the general arrangements.

4. Fire risk is reduced.

5. Passages and overhead spaces are clear from obstruction.

6. The power is under perfect control; its application is elastic in the widest sense, and the more intermittent the work the more apparent is the saving by electric transmission.

In conclusion, it is evident that the electric transmission of energy has won an important place in the field of civil and mechanical engineering, and is rapidly revolutionising the older methods. Indisputable evidences of the fact are

afforded by the many long-distance transmission installations in all parts of the world, generating power in bulk in remote places by the energy of falling water, and distributing it over large areas for lighting and driving mills and shops ; use in metallurgical works and electric cars, and which are being added to rapidly. Some of the more recent ones are Vouvry in Switzerland, utilising the water of Lake Tanay with a fall of 950 metres, and distributing electrical energy throughout the Rhone Valley to the amount of 12,000 h.-p. Single-phase alternating current is generated at a pressure of 6,000 volts and a periodicity of 50⌒.

Another in the Aude Department of France, distributes over 375 square miles three-phase current at a pressure of 20,000 volts, reduced for distribution locally to 130 volts ; the central distributing station being 43 miles from the power house.

In these countries it unfortunately happens that but few water-powers are available within commercial reach of manufacturing centres. Several power installations for general supply over large areas are, however, in course of construction in England and Scotland, and where these do not reach their place is filled by local city installations, originally started for lighting supply only. These have now realised the fact that the supply of energy for workshop uses can be profitably undertaken at a rate sufficiently low to induce manufacturers to remodel their arrangements, and there are now few large central stations which have not got a considerable proportion of their output taken for manufacturing purposes, from the large factory to the small artisan in a couple of rooms. The latter user, though individually apparently unimportant, is, collectively, a very considerable factor in the supply station's output, and I give in an appendix some particulars of actual costs for these small local industries, which may be of interest to those desiring to encourage the home-worker, and to improve the conditions under which he toils.

APPENDIX A.

Cost of Running Small Motors.

$\frac{1}{2}$ B.H.-P. motor, driving a circular saw for cutting picture mouldings, &c., used $2\frac{1}{3}$ units per week, costing, at 2d. per unit, $4\frac{1}{2}$d.

$\frac{1}{2}$ B.H.-P. motor, driving sausage machinery, used $4\frac{1}{2}$ units weekly, costing 9d. per week.

1 B.H.-P. motor, grinding coffee, running 10 hours daily, used 28 units weekly, total cost, 4s. 8d. per week.

1 B.H.-P. motor, driving printing press, 60 hours per week, used $18\frac{1}{2}$ units, costing 3s. 1d. weekly.

2 B.H.-P. motor, driving 30 sewing machines, 54 hours a week, used $34\frac{1}{2}$ units, costing 5s. 9d. weekly.

3 B.H.-P. motor, driving 10 Linotype machines, 36 hours a week, consumed $138\frac{1}{2}$ units, costing £1 3s. 1d. weekly.

1 B.H.-P. motor, driving cycle repairing machinery, cost £1 2s. 8d. for energy during 6 months, the previous bill for gas being £6 ; the electricity costing 2d. per unit, and the gas 3s. $4\frac{1}{2}$d. per 1,000 cubic ft.

The cost of printing a 12 page daily paper at the rate of 48,000 copies per hour is, approximately, $1\frac{1}{3}$ pence per 1,000, with energy charged at $1\frac{1}{2}$d. per unit.

APPENDIX B.

Average Dimensions, Weights, and Prices of Alternating Current Motors.

Single-Phase.

E.H.-P.	DIMENSIONS	WEIGHT	PRICE
1	15″ × 13″ × 10″ high	154 lbs.	£19 15 0
5	20″ × 17″ × 20″ ,,	440 ,,	46 0 0
10	28″ × 20″ × 24″ ,,	660 ,,	92 0 0
20	35″ × 24″ × 28″ ,,	1,100 ,,	144 0 0

Three-Phase.

E.H.-P.	DIMENSIONS	WEIGHT	PRICE
1	13″ × 11″ × 13″ high	110 lbs.	£16 0 0
5	18″ × 16″ × 18″ ,,	290 ,,	44 0 0
10	22″ × 18″ × 20″ ,,	430 ,,	64 10 0
25	35″ × 25″ × 29″ ,,	1,000 ,,	136 0 0

The PRESIDENT (Mr. J. H. Ryan) said he was sure the Members would all join him in according the author a hearty vote of thanks for the very interesting paper they had just heard.

It appeared to him, at least, that when the new Electric Power Station in Dublin was completed their city would be able to compare very favourably with other parts of the United Kingdom as far as electric power was concerned. There was therefore no reason that industries and manufactures of various kinds requiring power should not now spring up in their midst, besides giving additional zest to those already in existence. This, of course, depended on the price being sufficiently low to induce manufacturers to adopt electricity as a motive power.

MR. JAMES DILLON, in seconding the vote of thanks to the author, said he hoped it would lead to a good discussion. He would like to ask if the author could give them some idea of how the cost of maintenance compared with the cost of steam supply. They were aware that shafting when taken care of could be kept for a very considerable length of time.

He did not see anything in the paper indicating how the cost of maintenance for an electric installation would compare with the cost of maintenance when workshops are driven by steam. He thought it was important, in order to be able to compare the total cost of workshops supplied by steam and the difference when supplied and worked by electricity.

PROFESSOR LILLY said that the paper was an important one, in view of the many schemes now before the public for the electric transmission of energy, and he would like to make a few remarks on some of the points that had been raised.

The first was with reference to the transmission of power from large central stations. Would the consumer find it more economical than if supplied from a plant on his premises? It depended upon whether the consumer was using a large

amount of power, and had a continuous demand for it ; for
small powers and an intermittent demand motors would be
more convenient and as economical. For large powers and
a fairly continuous demand it would be quite as economical
to generate it on the spot. Efficiency was one thing and
convenience quite another, and they were the factors that
had to be considered when installing an electric plant. No
doubt convenience would lead to a large adoption of the
electric motor ; but he could not admit that if the consumer's
premises were at some distance from the generating station
they would be more efficient than if the power had been
generated on the spot. The loss by leakage had to be con-
sidered and the efficiency of conversion, both of which ad-
versely affected the larger power station.

With regard to the efficiency of the motor, so long as they
were used for the purpose for which they were designed,
very good results were obtained. If overloaded or put to
work for which they were not intended the result would
be very poor, and as a rule the efficient range of load and
speed for a given motor was not very large. In the *Engineer*
of Jan. 2, 1903, this had been alluded to with regard to the
driving of machine tools, of which the following was an
abstract :—

" We refer to the development of electrical driving of single
tools. Without wishing in any way to depreciate the good
work that has been done, we are compelled to admit that
the machine tool industry has not advanced as rapidly in
this direction as in others. A famous tool maker who has
given some attention to this question admitted to me not
long ago that electrical driving gears were at present little
better than makeshifts. Many of them are neat in appear-
ance, but involving the use of short belt drives or reducing
gearing of great ratio; they are not economical. For a
perfect electrical machine tool the maker wants a motor

with a good range of speed, and having the greatest torque at the lowest velocity, and with these qualities must be coupled small size for power. So far the electricians have failed to provide such a motor."

In making these remarks it was to show that the problem of driving tools or like plant by means of a motor was not a simple one, and that unless the motor was carefully selected for the work it had to do, the results would only do harm to the system advocated by the author. The whole problem of the introduction of electric energy into workshops depended upon what was wanted. If they wanted convenience certainly it was very convenient. Against this the very important question of economy had to be considered. Did their machines lie idle the best part of the day, if so, electric motors would be better than mechanical drives ; if not, but they were continuously at work, then mechanical driving would be as effective and economical.

In Mr. Langdon's experiments, quoted by the author, a certain amount of metal was taken off in a given time ; approximately he showed that the electric power required was only one-half the mechanical. This test was only a comparative one, and could not be used as an argument in favour of electric driving unless the length of shafting and other connections used in the mechanical drive were considered.

The question of cost is important. The first cost for fitting out a workshop with motors would probably be more expensive than mechanical drives, and he had come to this conclusion from an estimate of the cost of the two systems for a small workshop. If an electric system were to be used, which was the best to adopt ?

The three-phase system had been freely mentioned ; the single-phase also had many advocates. Would the three or single-phase be better than the direct current—he would like to have the author's opinion on this point.

MR. P. C. COWAN said he would like to know where the
author got £5 per annum per h.-p. as the average cost of
steam-power in Lancashire, as the figure seemed rather high,
considering what is now achieved with modern boilers and
engines.

There was a want in the paper of reference to Ireland and
the development of electrical work in Ireland.   The author
had told them of what occurred across the water and in other
countries, but left out Ireland altogether.

A great deal has been done in Cork, Belfast, and London-
derry on the lines to which the paper referred.

Professor Lilly had dealt with the subject in the abstract,
but he wished to mention what had actually been done by
business men in this country.

In Londonderry they had hundreds of sewing machines
in single factories running with electric motors, and in Belfast
they had for many years in the very large ship-building works
of Messrs. Workman & Clark heavy machinery driven by
electric motors.   In these two cases the current was generated
on the premises.

They had in Belfast a central station for supplying manu-
facturers with electric energy at the cost of about one penny
per unit, and the Corporation, under the powers of a local
Act, hire out motors to consumers.

In Derry the cost of private generation of electricity was
given, in evidence before him, as less than one penny per unit.

The question as to what was the best current to use was
raised a few years ago in connection with the very extensive
scheme of which the author would shortly have charge in
Dublin.   Certain gentlemen swore there was no such thing
as a continuous current motor.   The other side swore alter-
nating current machines were practically no use.   It ap-
peared, however, there were very many three-phase alter-
nating current motors running on the Continent.   He was

glad to hear the three-phase motor had now been brought to a high state of perfection.

MR. A. E. PORTE said, with reference to what the author said about the system of controlling motors, those of them who had any experience in dealing with electric transmission and the use of motors had found that it was absolutely of the first importance that the method of control should be placed out of the reach of the men. He had put in some motors in a workshop which were supposed to work at 35 ampères. On one occasion he came along and found one of the motors working at 65 ampères. The engineer had put in a fuse of about four times the working capacity. The life of the motor would be very short under those circumstances.

With regard to the crane mentioned by the author, either the motor referred to there was designed to take 100 per cent. overload, or there was something wrong in the calculation.

He had recently been working out some figures in connection with a similar case, and he found it would require a motor at 29·8 h.-p., and even that was to be used merely at hoisting. Traversing at 150 ft. per minute would require about 30 h.-p., and extra for slewing.

It was obvious that these Hammersmith crane motors must be able to stand an enormous overload. He would like some information on the subject, as the matter had a particular interest for him at present.

With reference to electric welding, for small weldings there was no doubt that electric welding was the thing.

The question of the adoption of electricity for power purposes was altogether one of cost. At what rate could they get the power supply. In America, Switzerland, and other countries they had water power which was utilised for generating current, and then they were able to transmit the current to unlimited distances. This enabled them to supply the current at a very low rate.

Mr. Cowan had referred to what had been done in this country. In Cork they had at present about 1,200 to 1,400 h.-p. in motors running every day.

When they saw, as he had recently, mechanical engineers taking out their engines, scrapping them, and adopting electrical driving instead, he considered there was a fair chance of motors becoming more general.

In his appendix the author had put down the cost at 2d. per unit. That might be all right up to 5 or 6 h.-p.; but if they went to about 10 h.-p. for say ten hours a day with the ordinary gas or oil engine, they would be able to get this at a cost of about 1¼d. or less with a decent engine. Therefore, if 2d. per unit is to be the charge for electricity in Dublin, he was afraid the prospect of any large development was remote. In Belfast the cost, as well as he could remember, was threepence per unit for the first hour, and one penny per unit afterwards, which averaged about 1⅛d. In Dublin it would probably be 7d., and 1d. which would average about 2·2d. per unit.

Small users as a rule do not run their power all day long; such people will only run about two or three hours a day. If these people are going to adopt electric driving they must get their supply at a price that will be certainly less than 2d. per unit. What that price will ultimately work out at, of course, they would have to rely upon the author to let them know.

The statistics about the Midland Railway works from Mr. Langdon were very interesting, and he was sure they might rely upon the figures being correct.

Mr. F. J. Dick said the paper dealt with the use of motors in workshops and factories, which led naturally to the subject of small industries, and with regard to that he thought many would like a little more information. He considered it would be of great advantage if they had more particulars as to the

actual cost of working small power motors from ¼ h.-p. upward. This might help in the development of small industries in small houses.

MR. G. MARSHALL HARRISS took exception to the title. He thought it was generally accepted that transmission of electrical energy, when mentioned, was intended to mean the transmission over a great distance, and when you hear of transformation it suggests transformers and the transformation from one pressure to another, or from alternating to direct currents. Beyond a passing remark, however, nothing of the kind was dealt with in the paper.

But Mr. Ruddle himself would appear to recognise that his title covers a wider field than he had touched, because he says he will only deal with one section of that field, and when that is so, why did he not label his paper that particular section?

He had dwelt upon this matter because he hoped by doing so he might get Mr. Ruddle to shift his ground a little, and if successful in doing that he thought he might be in a position to impose some penalty, and the one he would suggest—if he might—would be that Mr. Ruddle be asked to write another paper to justify the title of this one. That might appear rather hard, but, as the President pointed out, Mr. Ruddle will very shortly have in operation a very important scheme, embodying the transmission of electric energy on a large commercial scale, and its transformation also on a large scale, but in many ways quite new to us, on this side at all events, and on that account his paper would be all the more interesting and valuable.

With regard to Mr. Ruddle's comparison between direct and alternating currents for motors, he did not think it was necessary that if a direct current motor got jammed its armature must be burned out. He did not think Mr. Ruddle thought so, but it might appear that he did in the paper.

He thought one great advantage (not mentioned) that

alternating currents had, and that was—it was much easier to make and handier to use resistances, as the choking effect or self-induction of alternating currents assisted greatly. He had very much enjoyed hearing the paper read and discussed.

MR. BREW said with reference to the general question of cost in the working of motors and the development of a motor load, they had to contend with small steam engines, gas engines, and other sources of power. Take the case of a 10 h.-p. motor. If they took a steam plant of 10 h.-p. they knew how terribly inefficient it would be. The cost of the B. H.-P. per hour was anything from 4d. upward. It depended entirely upon the skill exercised by the stoker. If they came to the gas engine, and considered it running throughout the day continuously for about 10 hours, they got 1 B. H.-P. for 1d. to 1½d. per hour.

At first sight this appears to be a better result than can be obtained from the 10 h.-p. motor, and this would be disastrous for the electric motor ; but there was a very important point which had not been touched upon, and that was : That in the case of a 10 h.-p. gas engine, it would often happen that the machinery was stopped for some short time—10 to 15 minutes or so. They would seldom find that the engine would be stopped for this time, as the trouble in starting the gas engine was too much, and, therefore, it was left running at a loss rather than go to the trouble of stopping and starting.

The author had referred to the installation at Messrs. Siemen Brothers. He himself was on Messrs. Siemen's staff when this change was made from mechanical to electrical driving, and the result was very satisfactory. In this case they had continuous current motors. But among the several thousand workmen in the place there were a great number of practical electricians, which was of great advantage in the working of continuous current motors, for they required more attention than the three-phase type.

The central station there was often left in charge of an apprentice, so that it cost very little to run the installation.

With regard to the three-phase motor, it was undoubtedly the ideal motor in many ways. There was no commutator and brushes, and no chance of sparking. Practically, it could not be damaged if they tried.

In choosing a motor it was well to consider that with the three-phase motor, if they got a machine with higher speed, as a rule they had a higher power factor.

Another point to be considered was the question of torque. Taking the best of the continuous current motors, the series motor, the starting torque was about six times the running torque. In a good design of the three-phase motor they would find the maximum torque to be about four to five times the running torque.

If they came to the question of cost, they would find the two things nearly balanced one another, and they would find the three-phase was as cheap as the continuous current motor.

MR. PURCELL said there was just one point which he thought had been overlooked. In the City of Dublin they possessed a very great pressure in the Vartry supply. Motors worked by that were probably the cheapest motors worked in the United Kingdom. He believed the cost was 6d. per thousand gallons, at a pressure of 75 lbs. This he believed would work out at something like one-eighth of the cost of the motors under the new Corporation scheme. No doubt the author could give them the figures. They had this power at their disposal, and he thought the Corporation would be glad to let it out. It would be available at all hours.

MR. RUDDLE, in reply, thanked the members very sincerely for their hearty vote of thanks.

With reference to the cost of maintenance of electric driving as compared with mechanical, he regretted that he had been

unable to get any detailed statistics on that point, as the all-round saving with electric driving was so considerable that few users had thought it worth while to analyse the details. The total maintenance charges on the engines, boilers, dynamos, cables, motors, &c., in a factory which generated its own electric energy for driving came out under 6 per cent. of the total generating costs; so that it was obvious that the maintenance of the electric transmission arrangements themselves must be very low indeed.

As pointed out in the paper, the cables were motionless and subject to no wear and tear, and the motors required practically no attention as the bearings were self-oiling, and new bushes, when required, were simple in design and cheap.

The amount of belting (which is one of the most costly items of maintenance in mechanical transmission) is reduced to the minimum, and as the cost of stoppages through broken belts on main lines of shafting is eliminated, the maintenance all round must be much less than in the case of mechanical transmission. He hoped, however, at a future date to be able to give reliable statistics on the points raised by Mr. Dillon.

Professor Lilly raised the broad question as to whether the power generated by large installations for general supply to the public would be as cheap as if generated by an isolated plant in the factory itself. This, as he pointed out in his paper, must be determined for each individual case according to its special circumstances, and he would refer Professor Lilly to the instance mentioned in the paper of a Lancashire machine works which obtained its electric power from a public supply at approximately one-half the cost of self-contained generating plant. He was not quite clear if Professor Lilly considered that small steam-plants and mechanical transmission were to be preferred in some cases; he hoped not, as recent experience showed in every case a considerable

economy by the adoption of electric driving, especially where the supply could be obtained from public distributing mains. He was afraid that the tool-maker quoted by Professor Lilly was very unfortunate in his experience, or that he did not adapt the design of his tools to the new method of driving as well as he might. Of course, electric driving was still young, but rapid developments were being made in the direction of variable speed control, and it must be remembered that it is often quite a disadvantage to vary speeds from the standard found best for economical production by self-acting tools on piece work and repeat orders. At all events, the large number of factories that had adopted electric driving for all purposes, and found it satisfactory, would tend to show that the experience mentioned was not general.

Professor Lilly was under a misapprehension as to the efficiency of recent three-phase motors ; many types would stand an overload of 50 per cent., and show less than 5 per cent. loss in efficiency. With regard to Mr. Langdon's figures, he could not, of course, guarantee their accuracy, but he had every confidence that they were correct. On the question of prime cost, he thought that Professor Lilly must have been designing a workshop for some unusually special purpose when he found the cost of electric driving higher than mechanical, as in several instances he knew that the cost had worked out from 40 per cent. to 60 per cent. less. On the question of direct current *versus* three-phase supply to motors the only possible advantage direct current had at present was the greater flexibility of speed variation ; but this was being rapidly eliminated, and, as pointed out in the paper, the general tendency was to convert existing direct current installations to three-phase ones.

In reply to Mr. Cowan as to the cost of steam power in Lancashire he said that the exact figure recognised by mill-owners there was £4 18s. 9d. per h.-p. per annum, for regular

factory hours, and the load being as steady as could be found anywhere, it may be taken as a standard figure for the cost under actual working conditions, and with the most modern engines and boilers. He quite recognised that a good beginning had been made in Cork, Belfast, and other towns in Ireland, but it was principally for small motors, and as yet no large factories were equipped throughout with electric driving, and it was to call attention to the advantages of this method that he had brought the subject before the Institution. The scale of charges fixed by the Corporation of Dublin for the new supply was fairly reasonable for a first start, and would be gradually reduced as the demand for motive power increased. With regard to Mr. Porte's remarks upon the crane at Hammersmith, the figures given in the paper were quite correct, and the motors stood an overload of 50 per cent. without trouble.

With regard to the figures given in the appendix he would remind Mr. Porte that the price of gas was not over 2s. per 1,000 feet in the places from which the costs were taken, and it was satisfactory to find that even at 2d. per unit for electricity it could compete on very good terms with gas engines.

Mr. Harriss thought he was too hard on direct current motors when they got "jammed," but he was only quoting the experience of large users in every-day work. Of course the motor armature did not burn out in every instance, but it occurred frequently enough to make it a point to be considered. He hoped during the next session to return to the subject and deal with electric transmission in a wider sense than the time at his disposal at present permitted. He was glad to see that Mr. Brew was able, from his experience at Messrs. Siemen's, to confirm the fact that three-phase motors gave less trouble than direct current. On the question of first cost, the three-phase motor was now appreciably cheaper

than the direct current. With regard to Mr. Purcell's suggestion to use the Vartry supply to drive motors, as the ordinary pressure is only 40 lbs., and not 75 lbs. as stated by Mr. Purcell, he thought they would not prove very economical, and any large use of them would necessitate a large outlay in additional mains into the city to supply the new demand.

In conclusion, he desired to thank the various speakers for the thorough manner in which they had discussed the paper.

MR. ROBERT COCHRANE, Vice-President, in the Chair.

The transfer of MR. PATRICK F. O'SULLIVAN from the class of Associate Members to the class of Members was notified by the Council.

The following candidates were balloted for and duly elected :—

GEORGE DEANE ROE, FREDERICK VICTOR GALBRAITH, LIONEL NORMAN GALBRAITH, JAMES P. M'GRATH, as Associate Members, and ARTHUR A. M'ARDLE, as Associate.

Mr. John H. Ryan, President, in the Chair.

The transfer of Mr. John Quigley from the class of Associate Members to that of Members was notified by the Council.

The following candidates were balloted for and duly elected:—

John C. M'Candliss and Alexander Maxwell, as Associate Members.

The Destruction of Towns' Refuse and some of the Principles involved in the Construction of Refuse Destructors.

By H. Norman Leask, Associate Member.

(Plates I. and II.)

The question of the disposal of towns' refuse in a sanitary and economic manner is coming more forcibly before local authorities and their engineering advisers every day.

This appears to arise, in the majority of cases, from the fact that accommodation for tipping refuse within an economical carting distance of the sources of supply is daily becoming more difficult to find, if, indeed, it is not already extinct in many districts.

It is well known that towns' refuse consisting of all manner of *débris* has been deposited in hollows adjacent to residential property. When the hollows were filled, these baking or fermenting pits have been covered with soil and sods, and in many instances turned into recreation grounds. It has often happened that terraces of houses have been erected on these *desirable* (!) sites.

In a South of England town refuse has been deposited

within the gathering grounds of the water supply of the town, the water being pumped from wells within this area. In this case the refuse is sorted, the ashes and more combustible portion being separated from the vegetable and animal matter, the former being sold, the latter and more injurious portion being left to decompose within the area mentioned. At some of the so-called health resorts the towns' refuse is sold to farmers in the vicinity ; it is then spread on the land, with a result that is far from pleasing to residents and visitors. In London it has been, and in some cases still is, the custom to allow the poor to pick and sort the refuse before barging to sea. These are only one or two instances of insanitary methods of dealing with towns' refuse. To make a full catalogue would take up too much time and space. In the United Kingdom there are still some eight hundred towns of over 2,000 inhabitants without any means of disposing of the refuse beyond that of tipping.

Now that makers of high-class destructors are offering systems that with intelligent handling will effectually cremate refuse without the addition of any more highly carbonaceous fuel, sanitary authorities should not delay the erection of a destructor until all the space available for tipping has been filled. Some space may be required for depositing clinker in case this residual be not fully disposed of otherwise.

That refuse possesses the necessary amount of carbon by which it can be burned at a high rate of combustion is undeniable. In many instances brick makers buy it and use it as a fuel with which to burn their bricks.

The engineer to a borough in the South of England made a statement to the effect that the authorities there derive a revenue of £800 per annum from this source alone.

There are destructors up and down the country supplying steam for all manner of useful purposes, such as electrical traction, lighting, gasworks, pumping water or sewage, heat-

ing public baths and buildings, mortar grinding and paving block making.

With a view to obtaining a basis for an evaporative efficiency of a refuse destructor to be erected, the engineer of King's Norton, a suburb of Birmingham, had an analysis made of the refuse collected in the district. On specified dates each load of refuse was sampled as far as practicable ; the resulting samples were submitted to an analyst, with the astonishing result that the calorific value of the refuse was reported as about 4,500 B.T.U. Coal contains about 14,600 B.T.U.

The statement that the refuse contains 4,500 B.T.U. practically means that 1 lb. of refuse would evaporate $4\frac{1}{2}$ lbs. of water when burnt with atmospheric air in a furnace with all the heat utilised. Owing to furnace and boiler losses, however, only $1\frac{1}{2}$ to 2 lbs. evaporation can be looked for. The analysis of 1 lb. of refuse turned out as follows :—

Carbon	.	.	36·8	per cent.
Hydrogen	.	.	·29	,,
Nitrogen	.	.	·29	,,
Sulphur	.	.	·19	,,
Oxygen	.	.	7·3	,,
Ash	.	.	41·7	,,
Moisture	.	.	12·12	,,

100 per cent.

No doubt this is rather superior refuse. The amount of carbon varies considerably in different localities and seasons, and possibly falls below 20 per cent. of the whole in many cases. The amount of moisture also varies, and is very considerable where open ashpits are used. The average calorific value of towns' refuse in England might be taken as at 3,000 B.T.U.

A short sketch of the history of refuse destructors will, perhaps, be of interest. Destruction of refuse by fire was

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adopted by the ancients. This we have from Biblical knowledge and classical works. Fire is still employed in uncivilised countries, and indeed in several English towns the "everlasting" fires are in operation on their outskirts, burning refuse in the open.

The first authentic attempts made in this country to destroy refuse in furnaces dates back to about 40 years ago. These attempts were possibly made by dust contractors, but were not a success owing to the form of furnace being faulty in design, and the necessaries of combustion being denied the plant.

Then came the famous Bee-hive Destructor which was adopted in several large towns with but little success, and it has been said that this form of furnace laid the foundation for the objections which exist to-day among the public to the erection of refuse destructors.

Following hard upon this arrangement came the Fryers. This destructor exists to-day, but in a somewhat modified form. One of the first was erected in Manchester some 28 years ago and is still in operation. The Fryer furnace was manufactured by Messrs. Manlove & Alliott of Nottingham, and for many years it held the field, with the result that possibly this firm have erected the majority of destructors throughout the country. These furnaces were supplied with air for combustion by what is known as natural draught. Later, small boilers were placed in the flue leading to the chimney, the steam raised being used to drive mortar mills. It would appear from the various patents taken out to treat the gases resulting from the products of combustion, that this type of furnace was not all that could be desired, no doubt resulting from the low rate of combustion. The most notable, and certainly the most successful, attempt to treat the gases was that of the introduction of a separate coke fire in the flue, over which the gases or products of combustion passed. The air

supply being small CO or carbon monoxide, a poisonous gas
was formed. The coke fire supplied the necessary heat to
re-ignite this gas, and burn it to CO_2 or carbon dioxide, with
the help of free oxygen from the atmosphere. This arrange-
ment was patented by Charles Jones, Esq., M.I.C.E., and was
known as "Jones's Fume Cremator." Some of these installa-
tions exist to-day and are brought into use when the wind
blows a certain direction—that is, from the destructor towards
the town.

Following the Fryer type came the Horsfall Destructor,
patented by Mr. W. Horsfall of Leeds. This type was much
like the Fryer, but had an essential difference, the gases being
taken out of the furnace through an aperture in the roof,
situated at the front end of the grate, as against taking them
out at the rear. About 12 years ago these two types of de-
structors adopted forced draught. With the Fryer type a
fan was employed to produce the draught, and in the Horsfall
type a steam jet.

Up to the introduction of forced draught and higher
rates of combustion, many nuisances were created which
have not been without their effect to this day, and no
doubt the public still retain sentimental and other objec-
tions to destructors being erected consequent on the memory
of nuisances arising up to this period.

From this point more competitors entered the field and the
design of destructors, due to competition, showed a decided
advance in the right direction. Several new types came into
the market, and with them increased boiler plant was laid
down and higher temperatures maintained. The Fryer type
was re-arranged, and the boiler previously placed in the flue
was replaced by a small boiler placed between each pair of
cells. The Horsfall type was re-arranged, all the outlets
from the cells being directed into a large combustion chamber
at the end of which the boiler or boilers were situated.

Warner's Perfectus was the next type, much like the Fryer in appearance, the draught being supplied by fan.

Beaman & Deas's Furnace followed, in which case every two cells communicated directly with one another, but the products of combustion did not pass over the length of the two grates, but left the cell by crossing a bridge which ran the length of both grates. The gases then mixed in a common combustion chamber before entering the boiler.

Meldrum's Simplex followed. In this arrangement all the cells were coupled together, and communicated throughout to one end, where the common combustion chamber was situated. Steam jets and regenerative apparatus (a distinct advance) were employed for the production of the draught with this type.

Then came a lull of half a decade or so in the production of new existing types.

The Heenan Twin Cell, embodying the best modern principles, though in a somewhat crude form, then appeared. It consisted of a pair of cells communicating throughout to either end at will. Fans and regenerative apparatus were employed.

Hughes and Stirling appeared next, and consisted of a pair of grates communicating to one end—fans and steam jets being employed for the production of the draught.

A number of other types have lately been placed on the market, but have not as yet made any mark, and their various details are not common property.

The advent of forced draught into the design of refuse destructors brought high rates of combustion, high temperatures, and as a result considerable steam raising capacity. Nuisances ceased to exist from unburnt gases leaving the chimney, though they are still prevalent amongst older types still existing, and also with later types, arising from side issues due to the method of handling the refuse—for instance, the storing of refuse on a highly heated platform such as the roof

of the furnace, and the emission of clouds of smoke from the feeding and other openings.

Having more or less settled the question of combustion in the furnace, makers turned their attention to the economic aspect. Many and ingenious devices have been patented for reducing the cost of labour of working a destructor. Whether this question is finally solved or not is open to question.

There are practically only three systems in vogue to-day which tend to reduce the cost of labour below that of handling the refuse with forks and shovels. The first is patented by Messrs. Bulnois & Broide, and adopted by Messrs. Manlove & Alliott—the tipping of refuse into trolleys. The trolleys are divided into compartments, each compartment being capable of containing approximately one charge for the furnace (see Fig. 10). The trolley A is then drawn by means of an endless chain over the door to the charging opening B. Each compartment C has a door which, on the opening of the door B, drops and so discharges the charge on to the drying hearth of the furnace. The door B is then closed by a lever, and the process is gone through again in due course.

The second is that carried out by Messrs. Horsfall, of Leeds, and consists of a pit situated between a pair of furnaces placed back to back, and opening on to them. The opening at the tipping platform level is closed with a water sealed door. A van comes on to the floor, and the door D is swung back, and the contents of the van tipped direct into the pit, which also forms a drying hearth. The door is then closed and the material is drawn forward on to the grate by men with rakes working at the furnace door as before (see Fig. 11).

This arrangement eliminates the winch and endless chain which is essential in the first case, also the trolley; but whereas in the first arrangement only one charge is put into the furnace at a time, in the second a whole van load or

number of van loads are stored. In both cases when the
doors are open, owing to the hearths communicating directly
with the furnace, smoke and distilled gases issue forth until
the doors are closed again. The makers in the first instance
claim to reduce the cost of labour to 8¼d. per ton, and the
second party below that figure.

The third method is that adopted by Messrs. Heenan &
Froude, of Manchester, and consists of a hopper situate at the
back of each cell into which carts or vans tip any number of
loads up to their capacity. The hopper D (*see* Fig. 12) is
isolated from the furnace proper by means of a firebrick
lined door E, and from the tipping platform by means of a
ducking stool door F. The back of the hopper is so arranged
as to take the majority of the weight of the refuse.

In the base of the hopper a ram G works, which pushes the
refuse on to the grates H. The ram is arranged as in the
figure. You will notice that all the working parts are ex-
terior to the hopper, the weight and guiding of the ram being
taken on the rollers J. The ram is driven by a worm wheel
and screw. When a number of cells are coupled together the
shaft driving the machine is continuous, and on a furnace-
man desiring to charge his fire he puts a friction clutch in
gear and operates the ram until his furnace is filled with
sufficient refuse to cover the grates to the required depth.
The ram may also be constructed to travel the full length of
a range of cells and operate the whole battery.

The result of this arrangement is that fewer men than in
the before-mentioned cases are required. The men work
more efficiently with much shorter tools, and the real labour
is simply reduced to clinkering the fires. The whole opera-
tion of charging is carried out under closed doors, thus
preventing loss of heat and the issue of smoke or distilled
gases.

Having briefly touched on the history of refuse destructors,

a fuller description of several of the more modern forms of furnaces, with illustrations, may now be given.

The more modern types of furnaces are shown by Figs. 1 to 9.

The furnaces constructed by Messrs. Manlove, Alliott & Co., Ltd., Messrs. The Horsfall Destructor Co., Ltd., and Messrs. Goddard, Massey & Warner, have apparently changed but little in outline for some years. They are represented in Figs. 1, 2 and 3.

Various forms of hoppers and drying hearths have been associated with them with varying success. The Beaman & Deas type (Fig. 4) was the first direct departure from the above-mentioned types. This type has laid claim to being the first really high temperature destructor.

The Simplex Furnace (Fig. 5), constructed by Messrs. Meldrum Bros., Ltd., brought out a type that embodied apparently new features—the products of combustion having a lateral motion across each grate in turn, thus progressing towards the idea of mutual assistance from neighbouring fires. The absence of drying hearths in this type is a feature worthy of note. A steam jet is employed to produce the draught, and the air supply is heated by the waste gases escaping to the chimney. This type has been uniformly successful, which fact may be attributed to the makers attending to the scientific aspect of the laws of combustion and a rational form of furnace. Hand-firing of the refuse in the same manner as when coal is employed is the means taken in this case to feed the refuse on to the grates. This type naturally underwent a process of evolution, but the standard form was rapidly realised.

The next type, first known as the "Twin-Cell" and later as the "Heenan" Destructor (Figs. 6, 7 and 8), underwent four or five definite stages of evolution or growth. The first experiments were carried out at an experimental works built

for the patentee near Bolton.   Generally it was constructed
as shown in Fig. 6, and may be described as follows :—The
twin-cell consists of an equal number of grates coupled in pairs
with an outlet in the roof at the end of each grate.   The
outlet over a freshly charged cell was kept closed until the
adjacent grate was ready for a new charge.   On this grate
receiving a fresh charge the opening over it was then closed
and the first-mentioned aperture opened.   This arrangement
permitted of an alternate direction of the gases, the hotter
fire being always between the opening and the freshly charged
grate.   The arrangement was perfect in action, but the
durable construction of the dampers closing the openings
was found to be very difficult.

The draught employed with this system was a fan draught
with air heated by exhaust steam.   The next step made in this
type was the reduction of the number of openings in the roof
(see Fig. 7). The same purpose was fulfilled, for when the freshly
charged fire came under the opening, the gases being cool and
more dense had to rise through the gases coming from the
adjacent incandescent fire.   In order to increase the mutual
assistance of one fire to the other a deflecting arch was built
over the bridge between the two furnaces.   This arch pro-
jected the gases from one cell on to the material lying on the
adjacent grate.   With this type the heating of the air by
means of exhaust steam was dropped, and regenerative ap-
paratus was placed in the flue leading to the chimney, the
air so heated being dry, and not saturated.   The construction
of the deflecting arch above mentioned was not found satis-
factory, and with a view to obtaining greater mutual assistance
from the adjacent fires the arches over the grates were turned
in a direction at right angles to their original axis.   These
arches are carried in turn by another arch, which springs
across the bridge between each grate and takes the place of
the deflecting arch before mentioned (see Fig. 8).

The effect of this construction is to deflect the gases in a concentrated form and in a tangential direction to the soffit of the main arch, and so induce the gases to impinge on the material lying on the adjacent grate. This arrangement is now the standard constructed by Messrs. Heenan & Froude, Limited, and is giving unvaryingly successful results. An idea of the value of constructing the furnaces in this manner may be obtained from the following fact. Previous to the introduction of the deflecting arch it was necessary to leave some of the hot clinker on the grate before re-charging. This portion formed a nucleus of the fresh fires. It is now possible to entirely withdraw all the material from a grate about to be re-charged, as the action of the gases is to ignite the material lying on the grate, without loss of time, showing that there is a material advantage when the cells are worked in series.

Before leaving this type it might be mentioned that the air for combustion is drawn from the upper part of the building in which the destructor is situated, and driven by a large fan through an air heater or economiser constructed of a number of steel or iron tubes formed into a battery, and placed in the main flue, the air being delivered both above and below the grates. The heated and dried air (not saturated with steam) improves the combustion and raises the temperature in the cells by the increase in the temperature of the air; and further, as less air is required to complete combustion the resultant temperature is still higher. This will be shown by a calculation from first principles given later. Inrushes of cold air and outrushes of smoke are prevented, the pressures being balanced by the inletting of the air above the grate.

The next type, that known as Hughes & Stirling's, also contains the idea of mutual assistance to some degree. Fans and steam jets are both employed in this type, and a portion

of the air supply is slightly heated by being forced to follow
a passage of sinuous course through a firebrick wall situated
in the combustion chamber (Fig. 9).

Appended will be found a tabular statement of performances
of various destructors.   The letter A in the table refers to
plants constructed by the Horsfall Company; B, maker's
name uncertain; C, to plants constructed by Messrs. Meldrum
Bros.; D, to plants constructed by Messrs. Beaman & Deas;
E, plants constructed by Messrs. Heenan & Froude; F, plants
constructed by Messrs. Manlove & Alliott.

These tables have been compiled from published tests of
the various plants.   While tests to some extent have a meaning
they still remain tests, and are not the result of observations
taken under normal working conditions.   The h.-p. are all
calculated on a basis of 20 lbs. of steam per I.H.-P. per hour.
These tables are to the lay mind in many instances misleading.
The omission of a statement as to the conditions which surround
each plant, and which must ever vary, is, as a rule, con-
spicuous by its absence.

The means taken to heat the feed water, such as by live
steam, exhaust steam, or the heat from the waste gases;
the quantity of steam absorbed in producing the draught
and supplying the feed to the boilers, noting whether fans
or steam jets be employed in the individual case; the tem-
perature of the air entering the furnace; type and position
of boiler: all these being very important conditions, and
having a considerable bearing on what a plant might be
expected to do under altered conditions.

The conclusions that can be drawn from the evidence
(brought out by competition) contained in such summaries or
tables may be summed up as follows :—That the nearer the laws
regulating combustion are adhered to, the better the results
will be; in other words, the cubic capacity of each cell, grate
area, and area of outlets should be correctly proportioned.

Comparative Results from Six Distinct Types of Destructors in Twelve Towns (Lancashire and Yorkshire).

TOWN	Evaporation per lb. of Refuse	Average Steam Pressure	Temperature of Feed Water	Consumption of Refuse per Cell per 24 Hours	I.H.P. produced per ton of Refuse on basis of 20 lbs. of Steam per I.H.P.	Duration of Test	No. of Cells in use	Rate of Combustion per sq. ft. of Grate per hour	Boilers in use	Test conducted by
		Lbs.	Fahr.°	(T. c. q. lb.)	I.H.P.			Lbs.		
A. Oldham	·880	128	212	1 Cell, 7·96 tons	98	24 hours	10	25	2 Lancs. 30'×8'	Lord Kelvin
A. Moss-Side	1·35	190	46	1 „ 11·5 „	—	48 „	6	35·6	2 Babcock and Wilcox	H. B. Longley, Esq., Surveyor to the U.D.C.
B. Bury	·532	—	53	1 „ —	59·584	4 „	6	38·6	3 Multitubular	—
C. Rochdale	1·78	114	212	4 Grates, 50 15 1 4	199	6¼ „	4 Grates	54·9	1 Lancs. 30'×8'	F. W. Brookman, Health Supt.
C. Darwen	1·55	192	212	4 „ 52 2 1 6	173·6	48 „	4 „	56	do.	R. W. Smith Saville, Boro. Eng.
C. Nelson	1·516	118	212	4 „ 61 0 0 0	169·792	9¼ „	4 „	57	do.	J. A. Priestly, Health Supt.
C. Blackburn	1·39	90·8	212	2 „ 25 9 1 12	155·68	12 „	2 „	48	1 Lancs. 24'×7'	W. Stubbs, A.M.I.C.E., Boro. Eng.
D. Fleetwood	1·19	135	212	1 Cell, 21 11 2 2	138·28	8 „	2 Cells	80·5	1 Babcock and Wilcox	Messrs. Medhurst & Lloyd
D. St. Helen's	1·54	127	212	1 „ 27 12 0 8	172·48	7 „ 20 min.	2 „	108	1 do.	J. S. Highfield, Elec. Eng.
D. Warrington	1·14	68	104	1 „ 23 0 0 0	127	24 „	2 „	88·48	1 do.	George Darley
E. 1. Blackburn*	1·839	125	212	1 „ 10 10 0 0	206·10	8 months	2 „	39·00	2 Heenan patent water tube	W. Stubbs, A.M.I.C.E., Boro. Eng.
E. 2. do.	1·97	160	212	2 „ 59 18 1 0	220·6	3 „	4 Grates	57·72	1 Lancs. 30'×8'	do.
E. Wakefield†	1·612	125	212	1 „ 11 19 2 0	169·5	24 hours	1 Cell	45·0	1 Lancs. 24'×7'	C. M. Shaw, A.I.E.E., Elec. Eng.
F. Liverpool	1·173	—	212	1 „ 16 10 0 0	131·376	24 „	8 Cells	62·16	4 Babcock and Wilcox	—

* Cold air blast.   † Observations taken on 24 hours' normal working of the plant.   B, D, E, and F employ centrifugal fans.
A and C employ steam jets to produce the draught.

When those three claims are neglected good combustion cannot be expected. The amount of air required should be carefully ascertained by an analysis of the flue gases. If too small a supply be given, incomplete combustion, which means the forming of an excess of carbon monoxide; and if too great a supply, a low resultant temperature and excess of free oxygen.

To bring this paper, and more especially that portion of it which deals with the construction of the furnace and the system of draught employed, as applicable to the burning of refuse, within reasonable limits, the author would desire to submit the following points as being in the main uncontrovertible:—

That when attempts have been made to heat the air for combustion the higher and more regular are the temperatures maintained; * that the storage of refuse on the top of the cells was a pernicious habit, and gave rise to the chief complaint of nuisance; that drying hearths are entirely unnecessary, and, indeed, often a grave disadvantage; that cold air should be excluded from the furnaces, and that no openings for charging the refuse should be capable of acting as chimneys and so fill the enclosing buildings with smoke and vapours arising from partly consumed refuse.

When steam generation is one of the features required, it is essential that the form of boiler adopted be that most suitable for the peculiar necessities of the plant and the nature of the feed water. Further, it is no less important that the position of such boiler be decided with care. If situated too close to the furnace it has been found that the cooling surface is acted upon by gases only partially consumed, with the result that they are cooled and pass away in a noxious condition. We have an example of this in the black smoke nuisance which is such a common feature in coal-fired boiler installations. Most land boilers are set without due regard

* See *C* and *E* in Table.

to the fact that the coal used in the United Kingdom is rich in hydrocarbons and not anthracitic in character. On the other hand, if placed too far away, much of the available heat is dissipated before being utilised.

Again, it has been found that a high chimney not only represents a waste of money, but in the past has often been the cause of spreading a nuisance over an increased area.

The desire that still exists for the erection of a high chimney with a refuse destructor arises from the prevalent idea that the higher the chimney the less nuisance will arise. As a matter of fact the reverse is the case, for the product of combustion, if the air supply is what it ought to be, is not directly poisonous, and therefore may be delivered at a low elevation without fear of injury to plant or animal life, though it will not support either. Besides the products of combustion there is the inseparable element of dust to be dealt with, and with a high chimney the velocity of gas in the chimney is sufficiently great to carry the dust up and deliver it over an area which has a direct relation to the height of the chimney. Take for example a chimney 200 feet high, and calculate the velocity due to so-called "natural," but really "mechanical," draught. Assume that the temperature of the outside atmosphere is 62° Fah. and that its density D be ·0761, the temperature of the gas in the stack 500° Fah. and the density Dl ·0414. Now, assuming that there is no loss from friction and that the gases are taken as heated air, the difference of pressure can be obtained from the formula, $P = h \times (D - Dl)$, where P stands for the pressure and h for the height of the chimney. The result of the calculation is that the pressure difference equals about 7 lbs. per square foot of area of the chimney. The height of a column of air that would produce this pressure per square foot can be obtained from the formula $H = h \times (D - Dl) \div D$; the result of the calculation being 92 ft.

The velocity of the air into the base of the chimney can therefore be found from the following formula : $V = \sqrt{2gH}$. From this formula the velocity is found to be 76 feet per second, or about 52 miles per hour. Now, take a case of a chimney say half the height, with the same temperatures existing, and the velocity is reduced to about 37 miles per hour. Again, if the temperature be reduced to 250°, the density of the heated air becomes about ·056, which would further reduce the pressure difference and therefore the velocity, the result being a velocity of about 13 miles per hour. It can be seen therefore that when the height of the chimney is reduced, and the temperature of the gas also reduced, the velocity can be very much decreased. No account, for the sake of simplicity, has been taken of the friction set up in the stack, though it must be remembered this is by no means inconsiderable, as well as the alteration in the density of the gases. While this method of procedure for ascertaining the velocity of air or gas in a chimney where forced draught is applied is not correct, yet, unless the furnace is hermetically sealed to the outside atmosphere, and the fan takes the air from a closed reservoir, the condition that the height of the chimney and the temperature of the air therein affects the velocity must be duly allowed for. A good rule to follow is to arrange the area of the chimney so that, with the known quantity of air required for combustion, the velocity up the stack will not exceed 5 miles per hour, the chimney being taken at 80 to 100 feet high. Such a velocity will not be sufficient to hold the dust in suspension, and it must therefore be deposited in the flue. An experience illustrating this point may prove of interest. At a small town in Lancashire a destructor was erected, combining a furnace, boiler, fan, &c., coupled up to an existing stack about 100 feet in height. Against the wishes of the designer a bye-pass was installed as an afterthought, all the steam raised not

being required throughout the 24 hours. This meant that gases averaging in temperature about 1,800° Fah. were passed into the flue, consequently the chimney was taking from 4 to 5 times the original volume of air, the volume being doubled for a rise of about 470° Fah. of temperature. For the gas to escape it must necessarily travel at about 4 times the velocity it would have had had it first passed through the boiler, taking no account of the effect of the natural draught. The result was natural and what might have been expected— dust was held in suspension and ultimately delivered in the neighbourhood. On this effect being noted the designer's advice was taken, and the flue was increased in area about 600 per cent. To-day there is no dust belching from the chimney, all being deposited in the flues.

Regarding the nuisance of unconsumed gases; nothing will cure this after they have entered the chimney; and as they are heavier than air they are bound sooner or later, on cooling, to descend and give the nasty burnt odour one observes when in the region of a badly-designed plant.

The primary reason for a high chimney was to produce a draught mechanically by means of the heated gases in the stack. The introduction of forced draught removed this reason. All that is required now with a destructor is a low stack of large area, which is both inexpensive and does not form a land mark. The building of a high stack has before now been the cause of many claims being laid for injunctions against the working of a destructor. Even before a pound of refuse has been burnt in the furnaces, people have stated that they suffered from a nuisance. Under such circumstances this can only be attributed to the fact that a high stack attracting their attention so worked on their heated imagination as to make them believe that which never existed. It is interesting to know (though not forming part of the subject of this paper) that a chimney stack supplying air to a

range of boilers has an extremely low efficiency as a machine, and uses up possibly 5 per cent. of the coal bill in producing the draught as against one per cent. if mechanical draught were employed.

The provision of a drying hearth has a twofold bad effect : it reduces the total temperature in the furnace by having the material drying as well as burning on all grates at one and the same time ; whereas, if each grate out of a number be employed successively as a drying hearth, the drying process is only being carried out in one cell instead of the whole number in the same time. The second bad effect is that a quantity of volatile gas is being distilled, and finds its way out unburnt through all available outlets.

Perhaps the most troublesome feature to design in the arrangement of a refuse destructor, second only to the feeding of the furnaces, is the provision of a bye-pass between the cells and the steam generator, the reason being that it introduces dampers which are subjected to the maximum temperature, and further, by complicating the structure, adds materially to both its initial and subsequent cost. When a bye-pass is required, the chimney must of necessity be lined with an independent firebrick lining throughout, which means no small expense. The destructability of dampers in the bye-passes conduces to the very result they are designed to prevent—that is, " stoppages." If there is no power to work the fan or jets the cells must be idle, otherwise the burning of the refuse is liable to give rise to a nuisance. There is now a tendency to duplicate plants rather than complicate them.

It would not do to pass over the question of air supply and its production without going into the point more fully. Taking the question of production first. While there are makers of centrifugal draught fans and steam jets, or steam blasts, there will be a difference of opinion as to which of the two is most efficient and suitable. The case for each stands

thus :—From everyday practice on a coal-fired steam boiler installation it is found that with fan draught the fan engine absorbs not more than one per cent. of the steam raised to supply the necessary pressure and volume of air. In the absence of a series of tests made elsewhere the following table is taken from a published result of experiments on steam jets at New York Navy Yard :—

	Pounds of water evaporated per hour.	
	A	C
In boiler making steam	463·8	361·25
In boiler supplying steam jet ..	97·5	30·00
Per cent. of steam made as used in steam jet	21·20	8·30

These experiments were made with the object of obtaining the best form of jet for raising steam in launch boilers. It is stated that the idea of employing steam jets had to be set aside owing to the amount of steam used being too great. Now, taking the most economical case—viz., 8·30 per cent.—from the series, the two given being respectively the highest and the lowest in the list, the result does not appear in favour of the steam jet. When we consider that six to eight times, say, the quantity of refuse has to be burnt to evaporate the same amount of water as coal would, it can readily be seen that the percentage of steam required in both systems must rise considerably—in one case (of fans) say the 4 per cent., and in that of the jets to (about) 32 per cent. It may be said that the refuse only requires a fourth part of the air supply required for coal, and, therefore, would not require the same weight of steam in proportion. As, however, the pressure of the air blast has to be doubled when dealing with refuse, it may be taken that the above proportion exists. The makers of such apparatus claim that only 15% to 30% is absorbed for this purpose. It is often stated that steam jets form " water

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gas " in a refuse destructor furnace. It is well known that white hot coke gives off water gas when a steam jet is directed against it, but that the jet cannot be run continuously, otherwise the fire would be extinguished. It is fair to argue, therefore, that in a furnace where the temperature does not equal that of coke at a white heat water gas cannot be formed. In all calculations for the calorific value of a fuel the water present is deducted, and further, when oxygen is present with hydrogen in the fuel one-eighth part of the oxygen is subtracted from the hydrogen, and considered as forming water.

It would appear that what really happens in the furnace is, that heat is taken from the furnace to further heat the steam, but that when the gases cool again the steam or water vapour returns to water, and not unfrequently is to be found setting up corrosion at the back end of the boilers, or on the economisers placed in the flue. The use of a steam jet has, however, one good effect—that of cooling the clinkers in contact with the fire bars; the clinker is then more readily removed from the furnace. On the other hand, the saturation of the heated air before its entrance into the furnace destroys its capacity to absorb the moisture present in the fuel, and the exhaust steam from the fan engine may be employed to heat the feed water. Dry hot air, at 300° Fah., according to Mr. Thomas Box in his " Practical Treatise on Heat," has 200 times the capacity to absorb moisture that air at 60° Fah. possesses.

Turning now to the supply of air, the advantages of hot air for combustion might be touched on. Combustion is not a mechanical process, but a chemical one. Atoms of oxygen combine with atoms of carbon, with the result that heat is developed; therefore, when endeavouring to recover heat from refuse or other fuel a certain quantity of oxygen is required to unite with the carbon contained in the fuel, and

also in varying quantities for the other constituents such as sulphur, hydrogen, marsh gas, &c. Atmospheric air contains one part of oxygen in every five parts of air ; the other four parts may be taken as being composed of nitrogen. Nitrogen passes away inert in the furnaces. It can be seen, therefore, that the more closely we approximate to the correct air supply the higher will be the resultant temperature, as for every excess of oxygen we get a four times greater excess of nitrogen with its diluting properties. Pure air is composed by weight of ·236 parts oxygen and ·764 parts nitrogen. The air being heated to, say, 300° Fah. permits of the uniting of the particles of oxygen with the particles of carbon taking place with greater avidity, and is in effect a mechanical aid to a chemical process. From this it can be seen that less air will be required the higher the temperature of the air be raised. Taking average refuse as having a calorific value of 3,000 B.T.U., we can arrive at the temperature that may be expected in the furnace. We must, first, of necessity know what weight of air is required per lb. of refuse. An approximate formula for obtaining this is given below—

Weight of air in lbs. equals $12C + 36 (H—O \div 8)$.

C represents the carbon contained in the refuse, H the hydrogen, and O the oxygen. Taking the case of the analysis given in the earlier portion, the theoretical supply of air would be about 4·6 lbs. In practice it is never found possible to burn the material with exactly the theoretical quantity. We, therefore, assume that the refuse containing 3,000 B.T.U. would require say 6 lbs. of air if heated to 300 degrees Fah., and 8 lbs. of air if at ordinary temperatures. Now, since the specific heat of air is ·2375 times that of water, 1 lb. of air would be heated to 3,000, divided by ·24, or about 12,500° Fah., and 6 lbs. of air would be heated 2,080° Fah., and by adding the initial temperature of the air we get the total temperature equal to 2,380° Fah. When cold air

is used, 8 lbs. of air would be heated to 1,560° Fah., total temperature 1,620° Fah. These two results agree fairly well with actual practice on the same furnace, and show that the advantage of heating the air supply is of very great value. More perfect combustion and a higher temperature results with the consequent increase in the steam raising and sanitary efficiency. A plant with such an arrangement would have a practically smokeless chimney. Destructor chimneys are not usually what might be termed smoky, but a white vapour, or yellow coloured gas, is to be seen issuing from the top of the stack of many plants.

When the air supply is treated as above the top of the chimney hardly betrays the fact that the destructor is in operation.

It is very important that the analysis of the gases resulting from the combustion of the refuse should be taken at intervals.

An Orsat apparatus is a very simple instrument, and consists of 3 pipettes in connection with a graduated burette for measuring the volume of gas, and a pressure bottle to control the movement of gases undergoing analysis. The pipettes contain, respectively, potassium hydrate for the absorption of carbonic acid, an alkaline solution of potassium pyrogallate to absorb the oxygen, and cuprous chloride to absorb the carbonic oxide. A sample of the gases, extending over a period of considerable duration, should be taken, and by means of the pressure bottle a portion of the sample of flue gas is forced into the pipettes in the order named, and the amount absorbed by each is measured by means of the burette. Having obtained an analysis by volume in this manner we can by calculation obtain the proportion by weight, and so are in a position to judge whether too small or too large an air supply is being given to the fuel, or whether any leaks are present; the draught can then be regulated accordingly. Should there be any carbonic oxide present it will show that insufficient air is being supplied to

the fuel. On the other hand, if any quantity of free oxygen be present we may rest assured that too much air is being supplied. In both cases there is a loss of heat. In the first case it is due to the fact that when carbon is burned to CO only 4,400 B.T.U. are given off, and when carbon is burned to CO_2, 14,650 B.T.U. are given off. An excess of CO and O have the effect of reducing the percentage of CO_2. The closer the percentage of CO_2 is to 20 per cent. the better will be the combustion.

As an example of good combustion the following may be taken :—

CO_2 by vol.	-	17·2	per cent.
CO ,,	-	0·00	,,
O ,,	-	1·4	,,
N by diff.	-	81·4	,,

This is taken from the analysis of the flue gases where about 6 lbs. of air heated to 293 degrees Fah. was supplied per pound of refuse burned. It shows that possibly a smaller quantity of air might have been used, but not without fear of providing a percentage of CO.

While this paper does not attempt to deal exhaustively with the subject, it would be incomplete without some reference to the important question of the residuals. The quantity of residuals arising from the destruction of towns' refuse varies considerably, but may be taken to average 30 per cent. by weight of the refuse. Two conditions determine the proportion by weight of the residuals, the first necessarily being the nature of the refuse itself, and the second the amount of moisture contained therein.

In a district where fuel is abundant the percentage of ash is greater than in a district where trade and market refuse form the larger proportion. Again, where open asphits are in use, percentage of residuals is materially less than in cases where the refuse is of the same nature but deposited in covered

ashpits. This is due to the presence of moisture in the one, and its absence in the other. It is impossible to guarantee the percentage of residuals, though a guarantee to this effect is often asked for. A guarantee that should be sought is that the residuals should be entirely free from organic matter, and that the analysis of the gases passing away should show good combustion.

The purposes to which residuals can be put are numerous; the dust is often used as a base for disinfecting powder, tooth powder, or for plastering purposes. The large masses of clinker are usually broken in a crusher, then screened and sorted. The finer portions are used to make mortar; middle size for concrete work or bacteria beds in the place of coke. A simple method for breaking the clinker for this latter purpose is to spread it on a paved surface and run a steam road roller over it several times.

Another useful process is to make paving flags, the fine clinker being mixed with Portland cement in various proportions. The mixture is then put into a mould, over which a hydraulic press acts, a pressure from 3 to 5 tons being exerted on the flag. The flags are turned out in varying thicknesses, $2\frac{1}{2}$ inches to 3 inches. The flag can be removed from the press immediately and stacked to dry. They can almost be handled at once, but it is wiser to carry them on carriers, usually provided for the purpose. The flags can be manufactured at a cost of 1s. 7d. per yard, superficial, including labour and material, about 20 per hour being turned out by one machine.

Perhaps the latest development in the use of residuals is the making of bricks. This has been carried on very successfully on the Continent for some time, notably in Germany. A sample of the brick made is exhibited, and Fig. 13 illustrates a plant for the manufacture of the same.

The clinker is ground in an over-driven perforated edge-

runner slag crushing mill.   Perforated grates of the
requisite mesh are fixed in the pan.   The crushed clinker
is then elevated and mixed in a differential automatic mixer
and measurer with about 10 per cent. of lime.   Revivified
lime from gas works may be employed.   The lime is, as a
rule, slacked in a special drum for the purpose, the drum
being so constructed as to resist the pressure of the gas when
the lime is being slacked.   The mixture is then run through
another mill and is again elevated, and passes into the brick
making machine.   This machine is of the two-mould toggle
brick making type.   The bricks can then be put through
several processes of hardening, one of which is air-hardening
or natural maturing.   This may take from six weeks to three
months, according to the nature of the lime and clinker, and
thereby entails a large area of stacking ground.

Another system is to place the bricks as they are made in
an auto-clave or hardening cylinder, and, after hermetically
sealing the same, introduce steam at a pressure of about
100 lbs. for 12 hours.   At the expiration of this time the
bricks are allowed to cool, and are then ready for building
purposes.   The auto-clave is usually constructed to hold
about 8,000 bricks.   The brick exhibited is hardened by
natural maturing, and is now some six months old.

It is stated that the cost of making these bricks need not
exceed 14s. per 1,000.   This should prove a valuable asset in
a district where square bricks of uniform size and texture
are not to be had under 45s. per thousand.

The foregoing is an outline of the principles involved in the
construction of a refuse destructor.   The question of the
best type of boiler to employ with a refuse destructor installa-
tion has been purposely omitted.   Success or failure of a plant
cannot be placed to this account, provided always that the
type selected was of sufficient capacity, and suitable to the
conditions required.   The paper does not pretend to be

exhaustive. All the statements made are not foreshadowed in the tabular analysis of the performances of various types of refuse destructors. They are the outcome, however, of experience gained in the destructor field.

Taking all things into consideration, it is possible to erect a refuse destructor which will be as good a sanitary medium as a well-planned sewage scheme. Further, if careful selection be made of the various types, keeping in view the requirements before enumerated, it is possible to erect a destructor that would not prove an additional burden to the rate-payers, but a possible saving.

To obtain this desired end, the heat value of the refuse must be utilised for some such useful purpose as pumping sewage, water, or the generation of electrical energy for traction purposes, and the residuals dealt with in a manner suitable to the demands of the locality.

The PRESIDENT (MR. J. H. RYAN) said he was sure they would join with him in according a very hearty vote of thanks to the author for his exceedingly interesting and exhaustive paper, and also for the diagrams which he had gone to the trouble of preparing. They were further indebted to him for coming over from England to read the paper that night. He was not very familiar with the subject of the paper, but he hoped it would be productive of a good discussion.

There were one or two things which affected them all in a general way. They were sorry to see the immense amount of waste that was taking place in the City of Dublin, and if their Corporation would adopt some of the methods which the author had set forth, probably it would result in some benefit to the already overburdened taxpayers of Dublin.

With regard to the bricks which the author had alluded to, he had not stated to what tests these had been put, in the way of crushing or tensile strength.

MR. ALLANSON-WINN said he would like to ask the author if he had any experience in the burning of brick-clay by means of town refuse. He himself in India had burned many hundred thousand bricks by means of refuse collected from the towns and villages ; but whether that refuse was of the same kind as that with which the author had been in the habit of dealing, he was not in a position to judge.

It was a question which presented itself to them, for there were many large towns where the manufacture of bricks was carried on, and it seemed possible that the refuse might be utilised if its calorific value was sufficiently high to admit of its being used, not for grinding up to form the bricks, but for actually burning the clay. He thought that possibly this might be a means of using the refuse.

There was another point with reference to the clinkers. These might be used with advantage in the soleing of roads. He had used them himself for that purpose.

The soleing was not exposed to the actual wearing action of the wheels ; indeed no wheel should ever touch it. It was not necessary that it should be very heavy, as it was kept in place by the superimposed rolled metal. If a good hard clinker was laid down in layers of six or eight inches, then well rolled and covered with metal, he believed it would make a very good road.

He would like the author's opinion on these two points.

MR. M. PURCELL said there were one or two points with reference to the paper which the author had not mentioned.

They all knew the amount of refuse which went down their stream every day in the Eblana, and which might be utilised in that magnificent palace on the Pigeon House-road.

It would be a great boon if the author would tell them which of all these various destructors was the most efficient and economical, what was their various up-keeps per annum, and what was the wear and tear of each form.

This information would be of extreme value to all of them, and he was sure the author would give it to them with great pleasure, because, from his extensive knowledge, there was no doubt he could give them all the details of these plans.

MR. MONTGOMERY said he always found when dealing with such subjects that it was useful to get any information they could about works of the kind in their immediate locality.

He believed the Pembroke Urban Council had a destructor at the London Bridge-road Works, and it would be interesting if the author would tell them which of all the systems he had described was the one adopted at that works. Also, it would be interesting if the author could give them any information as to the amount of coal saved in producing steam at that works by using refuse instead of coal.

At the London Bridge-road works the steam made is used for the production of electricity, and from the electric output it could be easily calculated the coal required for this duty if that fuel were alone used. As, however, the steam is produced by burning refuse, to which a little coal is added, the difference between the cost of the calculated amount of coal required and of that actually used, represents the practical saving to the ratepayers due to the use of the destructor.

MR. LEASK, in reply, said he had no actual tests of the bricks, but he would get some tested and send on the results.*

With regard to the burning of bricks, this was largely done all through the London and Southern Districts. In the paper he had mentioned a case where £800 was received from brickmakers for refuse ; but in this case the Corporation

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* Since the above promise was made, the author has tested some of the bricks with the following result :—Bricks made from 100 parts clinker and 10 parts of lime crushed at a pressure of 250 tons per sq. ft. Red bricks manufactured at Bradford were tested at the same time, with the result that they crushed at a pressure of 227 tons per sq. ft. In order that the pressure might be evenly applied two thin strips of yellow pine timber were placed above and below the bricks when in the testing machine.

went to the expense of sifting all the ashes, and merely sold the more combustible portion to the brickmakers.

Near London he had seen the refuse tipped into fields, and then sorted out by men employed by the brickmakers, who would only take that portion which was suitable for their purpose, and left the undesirable portion on one side to decompose.

The great difficulty was to get anyone to take the whole of the refuse. In some districts the farmer will take the light portion, but not the tin cans, bottles, &c. Therefore, the only way was to burn it, and get the result in some other form.

The sample of the incrustation which he had there on analysis was found to contain salica, alumina, and iron. They would also note it had been molten, which proved that very high temperature existed in the furnaces.

The pyrometer was of no value to test the very high temperatures. The means sometimes adopted was to make small plaster-of-Paris cylinders, charged with an explosive, which exploded at various temperatures at different intervals of time. These were found more reliable than the ordinary means of taking temperatures.

The clinkers were largely used for roads. They formed an excellent bottom for new roads with good drainage. It also made very good concrete and mortar. Some Corporations were unable to supply all the demands for it.

He had been asked to state which, in his opinion, was the best destructor, but it was impossible for him to do so. He had endeavoured to make clear the principles that govern refuse destruction, but he did not wish to suggest which was the best. He must leave engineers to judge for themselves which particular type met these principles most closely. The destructor erected for the Pembroke Township is of the Horsfall type.

With regard to the amount of coal saved, that was a difficult question to answer. Electrical engineers had been very much against the introduction of refuse destructors in conjunction with power plants. They were always anxious to have a reliable source of energy, and for this purpose kept the steam up all the time on the coal-fired boilers, though they might only require to use the boilers for a short time. This prevented them from working the system as economically as they might if the boilers were not kept going all the time, and a proper system of mechanical draught installed to meet sudden demands. It had been proved that an average of 40 kilowatts can be got from a ton of refuse when burnt in a well-designed furnace.

A ton of refuse cannot generate 100 h.-p. per hour all the year round. People were likely sometimes to form exaggerated ideas about the value of refuse, and, therefore, expect to receive too much value from it. It was very wrong to add coal to refuse to increase its heat value, as the air supply required for refuse and coal were very different, and a good economic result could not be obtained from the combination.

Mr. John H. Ryan, President, in the Chair.

The following candidates were balloted for and duly
elected :—

Stephen Gerald Gallagher, as Member ; Lawford S. F.
Grant, as Associate Member ; Frederick Morgan Mooney,
as Associate.

Some Notes on Route Surveys with the Plane-Table in Egypt.

By J. T. Trevor Dillon (Assoc. Mem.).

(Plate III.).

The author proposes to give a short account of the methods
employed in making maps of the rough and mountainous
country in the Eastern Desert of Egypt, also of the Nile
Valley and Oases in the Lybian Desert for the Egyptian
Geological Survey, in the hope that it may be of some
interest.

That part of the Eastern Desert which was surveyed by
the author lies between lat. 26° and 28° 30', extending to a
distance of about 50 miles from the coast from Safaga Island,
in the Red Sea, to Ras Gharib,* in Gulf of Suez. The
country is very mountainous ; the main chain of the Red
Sea Hills runs in a N.W. direction at a distance (in northern
part of district) from the coast of 20 miles, approaching to
the sea near Safaga Island. A secondary and smaller range
runs along the coast, separated from the main chain by a
plain varying in breadth up to 14 miles. The mountains
are of a very rugged and precipitate nature, composed of
igneous rocks, principally granite, quite devoid of any vege-
tation, intersected by numerous wild gorges in all directions,

called " khors " or " wadys," and rise to a maximum height of 7,000 feet above the sea.   The hillsides are usually thickly covered by boulders of every size, all weathered to a spherical shape, but in some cases (Gebel Katar range for instance) bare masses of granite rise thousands of feet in almost perpendicular steps from the plain or wady.   There are generally some dried up shrubs in those wadys, and sometimes (considering the absence of water) a wonderful amount of green desert plants which are voraciously eaten up by the camels.   The floors are covered by sand and water-worn stones, and there is evidence of occasional very heavy local rain storms, as those stones (from the igneous range) can be seen lying in a watercourse near Quina, having been carried all the way to the Nile from the coast ranges.   The wadys are usually between 100 and 400 yards wide on their floors, with steep sides, so that there is a great difference in the temperature on the mountains and in the wadys, and in many of them the traveller passes scenery of the wildest and most weird description, of which Wady Barude, a narrow . defile six kilometres long, piercing the main range near the coast, is the most remarkable, the mountains rising perpendicularly on each side for the first 1,000 feet or so; this place and the Geb. Katar range to the north are worth a visit from the Nile ¿hemselves.

Plane-table.—The plane-table used contained none of the complicated adjustments found on the instruments employed by the United States Coast Survey, and on the Continent generally, which would have rendered them very liable to damage without any possibility of repair, and detract from their value and portability.

It consists of a light but strong wooden tripod attached to a brass head, and a wooden drawing board, about 2 ft. 6in. by 2 ft. 2 in., secured to the former by means of a screw and nut; the outer frame of the board is removable, and a damped sheet

of cloth-mounted paper being put on the centre, the frame is replaced, and by means of two hinged wooden flaps at either end, when they are pressed up, stretches the paper and leaves, on drying, a smooth surface to work upon.

Measuring Wheels.—On the desert surveys the distances between stations were recorded by measuring wheels, the revolutions being transferred by bevelled gearing to a small system of clockwork on the handle and indicated on a dial graduated in metres.

These wheels, however, did not last long owing to the rough character of the country, and were, moreover, a constant source of anxiety to the surveyor, owing to the inability of an Arab to wheel them in a straight line, and the strong inducement, especially in loose sand—should the plane-table party be making a detour from the path—for the native to lift the machine off the ground and carry it on his shoulder.

Tacheometer.—For the maps of the Nile Valley, which are on a larger scale, $\frac{1}{10000}$, and of a greater degree of accuracy, the author used a tacheometer which gave excellent results. It was similar to a 6 in. transit theodolite, but had four parallel and equidistant spider lines fixed in the diaphragm, spaced in such a way that the intercept on a levelling staff multiplied by a constant "K" for the instrument gave the distance in metres.

It was also supplied with an anallatic lense which obviates the necessity of adding to each distance measured a second constant—namely, the focal length of the object glass, plus its distance from axis of instrument—as would have to be done with an ordinary theodolite if used for this purpose.

The author's instrument was designed by Troughton and Sims, so that the constant "K" should be exactly equal to 100, and being tested at Cairo over carefully measured lengths of from 50 to 400 metres, the error of the instru-

ment varied from $\frac{1}{10}$ to $\frac{1}{40}$ per cent. This type of tache-ometer, or telemeter as it is sometimes called, is preferable to that in which micrometers are used, provided the distances to be measured do not exceed 350 or, at most, 400 metres, as it may be employed to read horizontal angles and to take rough astronomical observations in case a larger theodolite should not be available.

Compasses.—The remaining equipment consisted of a few trough compasses, 6 in. needles reading either side of the North to 5 degrees.

Alidade.—An alidade, or plane sighted ruler of the simplest construction, having two movable metal arms, in one of which a fine wire was fixed vertically in an opening, to be sighted through a narrow slit in the other.

Aneroid.—A 3½ in. aneroid in case, reading to 15,000 feet, and a good pair of field glasses ; Zeis's is the most suitable pattern.

Method of Procedure.—The method of working adopted was as follows :—A suitable point is selected near a town connected by telegraph with Cairo, generally at some Government building from which there is a stretch of hard and level ground at least three kilometres long in the direction of advance, on which a base can be measured with the wheel. Then its latitude and longitude are accurately determined by astronomical observations with a transit theodolite—the former by means of north and south stars, and the latter by time signals by telegraph, all of which opera-tions will be described later. Having set up the table, after due consideration, the first station is plotted in such a position that the line of route shall lie as near the centre of the sheet as possible, and that some distant landmarks which will be visible from the further end of the sheet may be taken in.

Next, the compass is placed and adjusted on the map, and

the magnetic North drawn on; rays are taken with the alidade to all the principal points. The measuring wheel having previously been carefully run over an accurately chained distance of 200 metres ten times, and its error found by taking the means of all the reading, is now sent along in a straight line for the next station, to which a ray had been drawn on the map.

On arrival at the next station, the table is set up by means of the direction ray from the last; all the points are again sighted and intersected on the paper. The base having been measured with accuracy, these objects may be considered as fixed, though under ordinary circumstances they would not, until sighted from three stations. The details are sketched in by hand in the ordinary way, using guiding rays as much as possible. Should the compass, when placed in position, now point to Zero on scale, all is well, but if not, the error may be due to one of two causes—(1) shifting of the plane-table while at work, (2) the needle being acted upon by some external object or objects in its immediate vicinity.

In the former case this can be avoided by, just before leaving the station, placing the alidade along the first ray taken and seeing whether the object is still sighted accurately ; in the latter, by finding whether there are any igneous rocks about, and testing the compass with a piece, also examining the table for any iron screws, nails, &c. In one table which had been repaired the author found several iron screws which so affected a compass that it could not be used.

Obtaining Local Names of Points Fixed.—Before leaving a station it ought to be ascertained from the table-men (who should be thoroughly conversant with the country) whether any of the objects sighted possess names, which are noted on the map, though only provisionally, until corroborated.

On approaching the end of a sheet, two conspicuous points

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at least should be accurately fixed lying as near the cut-off line as possible; these, when a fresh sheet is put on, must be pricked through together with the magnetic North line from the old one, and checked.

The hills in the author's maps were all sketched in by broken horizontal contours, as, after a little practice, a better representation of the features of the country can be given than by vertical shading, and the direction of drainage is marked on all wadys.

Nile Valley.—In the maps of the Nile Valley, some saplmes of which are here for inspection, the method of working was similar, except that a large number of points especially the village boundaries and cultivated land, (which both had to be accurately plotted in detail), were fixed directly by the tacheometer, as, being generally close at hand, they might not be visible from the next station. It was necessary to have a line of stations on each bank of the river, though the summits of hills, mouths of wadys, sheiks' tombs, &c., and other objects were generally fixed from the first set of positions. One of the most important and at the same time difficult part of this survey was obtaining the correct names of all the small villages which in some districts are under 500 metres apart. The natives often give different names from what motive, unless it be ignorance, it is difficult to say, when it is necessary to send for the Sheik or Omdi (magistrate), if there is one, for the correct information. These maps from Assouan to Korosko are published by the Egyptian Government on the same scale as they are drawn, having been reproduced exactly as they were drawn on the plane-table, and have been recently used by the Government on which to mark the limits of the new Assouan reservoir water levels, in connection with the compensation claims for buildings to be submerged.

Sources of Error; Stations fixed without Intersections.—(1) A

common source of error arises from plotting stations directly by the readings of measuring wheels or other similar method without obtaining intersections from fixed points, and especially so when such stations lie on hill-tops, on account of the distances only being measured to the base. These remarks, however, do not apply to a tacheometer, which by means of a set of tables can read distances from any position.

Compass.—(2) Errors due to the magnetic influence of the surrounding rocks. Many of the dolerites and diorites met with in the Eastern Desert affect the needle; even on granite hills the compass is sometimes found to be unreliable, the cause of which is not at first apparent, but on examination is generally found to be due to the presence of dykes of diorite or other rock in the granite.

Want of Rigidity in Plane-table Stand.—(3) Errors produced by want of rigidity in the table. In very dry climates the legs, if wooden, are liable to shrink, causing a certain amount of play where they are fixed to the brass stand, which is of course exaggerated on the plane-table, if the joints are not kept well tightened up. In some instruments this is guarded against, and cannot occur.

Wind.—(4) The author experienced sometimes for weeks very high winds, often necessitating, especially on hill-tops, the table being held in position, and even then, owing to the continued vibration, it is difficult to prevent its shifting out of azimuth. If one cannot get to the lee of some rock or other projection it is preferable to move down till a sheltered position is got, taking care to keep in line with the last station, and when all the sights have been taken the table may be replaced on top, in order to sketch in any details not seen from the previous position.

Tacheometer Errors.—(5) When the staff is not held at right angles to the axis of instrument the reading is inaccurate; this can be obviated by having a plummet and

string attached to the bottom length of staff at one side.
When the point observed is above or below the instrument
the angle of elevation or depression at which the reading is
taken is noted, the correction obtained directly from a table
supplied for the purpose, and is then deducted from the
observed distance.

Inclination of Table.—(6) Errors induced by the table
being out of level may give rise to some inaccuracy in sighting
a distant point.   A deviation from the horizontal of 6°
produces only a max. azimuth error of 9′, but this ought
to be easily detected by the eye ; and anything less may be
neglected, as a deviation of 5° produces $6\frac{1}{2}′$, 4° 4′, $3° 2\frac{1}{3}′$, and
so on.

Difficulties to Contend with.—When working in an unex-
plored country without triangulated points the surveyor
meets with many difficulties, to overcome which he must
possess both resourcefulness and patience, as they cannot be
foreseen.   But one or two cases deserve notice as they
constantly arise.

Recognising Points from Different Positions.—In a moun-
tainous country there is much difficulty at times in recognising
the different points after a change of position, which may be
invisible when passing along the wadys between stations, with
the result that on ascending to the next station many of them
will be found to have altered remarkably in appearance.   It
is important therefore, to examine the objects selected in the
first instance with good field glasses, and carefully note any
distinguishing feature they possess, making a rough sketch of
each on the plane-table sheet near its direction ray.

Cairns on Table Stations.—In some places the author found
it most useful before leaving a station on a hill summit to
erect a cairn of loose stones, from 3 to 5 ft. high, especially
should any of these points come within a subsequent sheet, as
they can then be easily recognised.

Owing to the extraordinary clearness of the desert atmosphere, it is not easy at first to judge distances accurately, but asisstance can often be got by comparing an object with one already fixed.

Wind and Sand.—Few, except those who have experienced it, can imagine the discomfort caused by sand and wind to travellers in the coast ranges of the Eastern Desert of Egypt, during certain seasons.   The author has experienced high winds with driving sand for three weeks at a stretch, with not more than a day or two interval all the time.   Work had to be discontinued on more than one occasion, but owing to the scarcity of water and distance between good wells (many of those in this region are very brackish, and cannot even be used by camels), one cannot halt at a place for any length of time as both men and beasts require a fresh supply of water every six days.

But plane-tabling under these conditions is a great strain on the eyes; after a week or so they are liable to become extremely painful.   It is necessary during such weather to bathe them with a weak solution of boracic acid or other remedy each evening, on return to camp, otherwise inflammation may ensue.

Rain is of rare occurrence in the desert, but shortly after starting on a traverse across to the Kharja Oasis, west of the Nile, several long and heavy showers were experienced one evening, and the next morning the country was enveloped in a cold Scotch mist, so dense that there was great difficulty in keeping all the camels together, not being on a road but proceeding by compass.

Musical Sand.—While on the subject of sand, the following peculiar phenomenon which was witnessed by the author may be of some interest :—

He had ascended a hill 380 feet in height above camp, rising on the south side almost perpendicularly for over 200

feet to the summit. As the prevailing winds are northerly, a large bank of sand had accumulated on the lee side, reaching up to the summit. While engaged with the plane-table some of the Arabs had been amusing themselves rolling stones down the slope, and in about five minutes a sound, which can only be described as like a musical humming top, but deeper in tone, was heard, faintly at first, but increasing, and it could not be discerned in the least from which direction it came; it then gradually subsided, having lasted about fifteen minutes. This humming sound was probably due to vibration in the air, between the sand particles which were slowly moving over one another under pressure.

The sand was lying at about 38° with the horizontal slightly over its angle of repose, and when equilibrium was disturbed by the stones the surface layer began to move down slowly, which movement was communicated to the underlying layers, and also extended largely over the surface; this musical sand, as the natives call it, has been observed before on occasions by travellers.

Hill Climbing.—In the Eastern Desert, most of the plane-table stations are necessarily on hill summits, many of which are extremely difficult of ascent, both on account of their precipitous nature and the loose boulders which if disturbed bring down an avalanche of rock *débris.* Therefore unless care be exercised in transporting an unwieldy instrument like a plane-table, it is bound to get damaged, if not smashed completely; it is advisable for the table to be kept in front in ascending, for if any stones be dislodged in front (no matter how cautious one may be this cannot always be prevented), a native with a plane-table on his back might not be able to jump clear in time, so that the instrument may have to be sacrificed to save himself. On one occasion the author would have lost both table and man but for a large boulder that happened to be by his side, and, being an active

fellow, he managed to get behind it in time to save himself
from an avalanche of stones, which would have swept both
table and man down the mountain, 300 to 400 feet.   This was
caused by the man in front coming upon and disturbing a
bank of loose *débris*.

Weathering of Rocks by Expansion and Contraction.—There
is a tremendous daily range of temperature on these
mountains in spring-time, 75° and even 80° having been
experienced by the author between sunrise and 1 p.m.;
this causes rock like granite to weather in a most remark-
able manner, assuming spheroidal shapes invariably and very
rapidly, owing to the sudden contraction and expansion,
with the result that occasionally masses of rock become
detached, generally during extremes of temperature, and are
dashed down the mountain side.   The author, when work-
ing on the summit of Gebel Fatiri—the highest and most
precipitous peak in that district—one afternoon, heard a
deep rumbling noise, lasting a minute or two, due to the
cause above stated, the noise being reverberated among
the precipices, which extended from almost the summit to
the base on one side in the form of a crescent, producing
an effect very similar to a peal of thunder.

*Water Flowing into the River Nile from the Lybian
Desert.*—A rather interesting fact was observed when on the
Nile, at a place called Dakka, in Nubia.   There is a patch
of cultivation about 2,000 metres long by 500 metres broad
on the west bank, under a kilometre from the river, and is
supplied with water by numerous sagas or native water-
wheels, which draw from pits sunk on the cultivated land.
The author noticed how beautifully clear and sparkling this
water appeared, and on proceeding to examine it found it
quite warm to the touch, and impregnated by sulphuretted
hydrogen; there was a difference of about 10° Fah. in
temperature from the river.   Where, then, was it coming

from? It certainly was not flowing from the Nile. This matter had been previously reported to the Public Works Department, and there are several theories as to its origin, the most probable being that this water travels underground from the high plateau in the Central Sahara in the region of periodical rains.

Constant Rate of Travel of Baggage Camels.—When crossing large plains or making traverses in the Western Desert, there being no other suitable means of measuring distances travelled, advantage was taken of a well-known peculiarity of the Egyptian baggage camel—namely, its constant rate of progress over smooth ground, almost 4 kilometres per hour. The author, on more than one occasion, tested them with a measuring wheel, and found it hardly ever to vary from 4 kilometres per hour; this was very noticeable during a journey across the desert to the Oasis of Kharga, when, though the camels travelled 9 hours a day, their rate of progress never varied from the start to the halt in the evening.

Astronomical Observations.—In countries where there are no triangulation points astronomical observations are of great importance; therefore, a few remarks of the methods adopted on those surveys may be of interest, as by those means the errors in latitude may be eliminated, and in departures kept within certain limits in the maps. A good 8″, or 12″ transit theodolite, a semi-chronometer watch with Kew certificate, a nautical almanack, and star charts are necessary. In the desert surveys an 8″ theodolite was used, and no difficulty experienced in transporting it even in the roughest country. They were always packed on the camel under supervision, a servant told off specially to look after them on the march, and the sheik of the camel men held responsible that instruments are carefully handled by his men.

Latitude.—Observations for latitude were taken every evening in camp, generally by altitude of the Pole Star

(Polaris). Readings face right and face left, to eliminate instumental error, being taken, the latitude can be easily worked out by a method shown in Nautical Almanack. When a more accurate result was required the method of north and south stars was used, which consists in observing the altitude and time at which two stars on opposite sides of, but about equidistant from, the zenith cross the meridian of place. The principle is as follows:—Let S_1 denote a circumpolar star between zenith and pole, Z_1 and δ_1 being its meridian zenith distance and declination respectively, S_2 a star culminating on opposite side of zenith, Z_2 and δ_2 its meridian zenith distance and declination respectively. Then

$$\text{(Lat.)} \quad L_1 = \delta_1 - Z_1$$
$$L_2 = \delta_2 + Z_2$$
$$\text{Mean lat. } L = \frac{\delta_1 + \delta_2}{2} + \frac{Z_2 - Z_1}{2}$$

Having computed the approximate time of both stars' transit from the R.A. given in the N.A. (which is the S.T. of transit) observations should be commenced about 10 or 15 minutes beforehand. The meridian zenith distance of each star is afterwards accurately obtained from the following formula, which is a development of that for the relations between one angle and three sides of a spherical triangle :—

$$Z^m = Z - \frac{\text{Cos. } \phi \; \text{Cos. } \delta}{\text{Sin } Z_1} \times \frac{2 \; \text{Sin}^2 \frac{t}{2}}{\text{Sin } 1''}$$

Where Z is observed zenith distance, ϕ the approximate latitude obtained from the maximum observed altitude $(90 - Z_1)$ and $t = $ hour angle of star. From the principle of this method it can be seen that the accuracy of result depends on the difference of zenith distance of the stars, which eliminates instrumental errors as well as those caused by refraction. This is an advantage, but on the other hand the working out of this observation is rather tedious. By this

method the latitude of a place can be fixed to within 200 to 300 feet without difficulty.

Time Observations.—Time observations were generally taken at intervals of 3 or 4 days when on the march, and always in conjunction with latitude observations. The local mean time was generally obtained as follows:—Two stars east and west of the meridian of place being chosen, whose declination and right ascension are given in the N.A., and their position at time of observation being as close to the prime vertical as possible, and of nearly the same altitude. A set of observations, face right and left, are now taken, and the mean altitude and mean time of observation of each deduced; now the three sides of triangle formed by the zenith, pole, and star are known, which are the co-altitude or zenith dist., co-latitude (latitude of place being known) and co-declination; from this the hour-angle of star can be deduced by formula for the solution of a spherical triangle whose sides are known, of which the following is an adaptation:—

$$\tan \frac{t}{2} = \sqrt{\cos \delta \; \text{Sin} \; (s - h) \; \text{cosec} \; (s - \phi) \; \text{Sec} \; (s - p)}$$

Where h = mean of observed altitude after the corrections for refraction have been applied.

ϕ = latitude of place.

p = polar distance of star.

t = H.A. at observation.

$s = \dfrac{h + \phi + p.}{2}$

The L.S.T. of L.M.N. must now be obtained from the N.A. by applying the correction for the retardation of M.T. on S.T., viz.:—9·86″ per hour, for the longitude of station of observation to the G.S.T. of previous G.M.N. The H.A. of star is next obtained from the above formula, thus added to stars R.A. gives L.S.T. of observation, subtract it from the L.S.T. of L.M.N. for the S.T. interval between

observation and previous noon, which is reduced to mean time by table of equivalents. This is the time L.M.T. of observation, and the difference between it and the mean of observed times is the correction to be applied to the chronometer. This method gives true local time to within 1″, requires the approximate latitude to be known and also longitude. A small error in assumed longitude hardly effects the result; it is best obtained by scaling off the departure on the map sheets from the base station.

Longitude.—It is difficult to obtain longitude observations of sufficient accuracy to be of use as a check on the maps when engaged in a traverse at a distance from telegraph stations.   In the author's traverses in the Eastern Desert it was necessary to depend on the time observations, which served to keep errors in departure or longitude within reasonable limits, by comparing correct L.M.T. with that at the base station, the rate of chronometer being known from that point.

Azimuth.—When working in the Nile Valley, observations for longitude were not taken, as the departure is so small they would be useless as a check on position of station. But by means of azimuth observations, small errors in departure can be easily eliminated when the line of advance is in a southerly or northerly direction, as in this case.   A suitable station was selected at the commencement of the traverse outside Shellal Post Office, whose position was known accurately by a series of observation for latitude and longitude (by telegraphic time signals from Cairo), a distant and distinctive hill summit sighted by telescope, and its bearings taken, next the bearing of true N. and S. line obtained and the bearings compared, which gives the azimuth of the first point.   When the maps advanced to this summit, which was carefully fixed by intersections on plane-table, observation for latitude and the bearing of

another point or points in advance were taken. The distance between azimuth stations was usually between 8 and 14 kilometres, though occasionally, from a good position, points 30 kilometres were observed. There are several methods for obtaining the true N. and S. line; observation of circumpolar stars at elongation was found to be the most convenient for the purpose, especially as the latitude was in each case known, and, thus, only one elongation observation was necessary.

A suitable star, whose declination is given in the N.A., and well exceeds the latitude of place, is chosen, and its approximate time of elongation computed. It is observed shortly before the calculated time, and when the motion becomes vertical the bearing taken. As the vertical movement continues for some distance there is time for a second observation with telescope turned through 180° and reversed, if there is a chance of instrumental error in horizontal axis. To the bearing at culmination add the star's polar distance, which gives a fair approximation of meridian, and hence the azimuth of distant point is known.

It is preferable to set up an instrument shortly before sunset to take the bearing of the required object, but it must remain under observation till the reading of stars are obtained.

How to Obtain the Best Results of Plane-table.—In conclusion, a plane-table worked with graphic triangulation, as described in this paper, cannot be considered an instrument of precision; but if the following points be observed, very good and useful work can be done in a very rough and practically unexplored country, such as that lying between the Nile and the Red Sea coast, when stations are fixed frequently by astronomical observation with a good 8″ or 12″ transit theodolite :—

(1) Choose and fix points which are visible from most

positions on the sheet, and easily recognised when viewed from different directions.

(2) Take stations from which a good view of the immediate neighbourhood can be obtained.

(3) Fix these stations as far as possible by points whose positions have been accurately determined, and avoid using those obtained by acute intersections.

(4) Before proceeding to a new station draw a direction ray to it, which should afterwards be used to sight back on, as a check on the compass. In practice it is advisable to select more than one point, as, on closer examination, the position may prove inaccessible or unsuited in other ways.

(5) Take rays to well-known summits however distant, which, though not being mapped at the time, serve to link together the work of other parties, thereby affording considerable assistance when the map sheets are being finally compiled and plotted.

(6) Use a tacheometer in preference to any other instrument for measuring distances between stations when there are not sufficient fixed points available. When three or more points whose positions have been accurately determined are visible, one is independent of measuring instruments, and, if necessary, of the magnetic compass, and the table can be oriented either by the method explained in paragraph 4, or by interpolation. But often this is not possible, as, for instance, when crossing a plain where the hills or other physical features are out of reach; recourse must then be had to the tacheometer, measuring wheel or other methods.

ABBREVIATIONS.

G.S.T. = Greenwich sideral time.
G.M.N. =   ,,   mean noon.
L.S.T. = Local sideral time.
L.M.T. =   ,,   mean time.
H.A. = Hour angle.
R.A. = Right ascension.
N.A. = Nautical almanack.

The PRESIDENT (Mr. J. H. Ryan) said he was sure all the members would join with him in according a very hearty vote of thanks to the author for his very interesting paper, and also for the beautiful photographs which he had taken the trouble to exhibit to them that evening.

The paper showed the importance to all young members of the profession, who contemplated going abroad, of having a good knowledge of instrumental surveys, particularly tacheometry and latitude.

Many years ago the members of the profession had no opportunities of learning these things, except what they were able to pick up in practice. They were not taught these things in Trinity College.

He hoped in the modern systems of culture, where these matters were looked into, the youthful members of the profession would benefit thereby.

PROFESSOR LILLY said he had much pleasure in rising to support the vote of thanks to the author for his most interesting paper.

With regard to the plane-table it could not be looked upon as an instrument of very great accuracy, and was more useful for such surveys as had been described by the author than for detailed surveys. It was for this reason that the instrument was so much used abroad, where reliable maps of the districts could not be obtained and a reliable map of the formation of the country was required rather than a detailed survey. The usefulness of the plane-table had been much extended by mounting a tacheometer on the alidade. On the Continent the instrument had been much used in this form.

It had occurred to him that the objection to the use of the plane-table, which required that the instrument should be set up from two stations to fix the position of a point, could be overcome by using a mirror at one station to reflect the image to the station at which the plane-table was fixed.

Professor Alexander and himself had essayed to design such a surveying instrument, which he hoped in the near future to get manufactured and tested.

He would like to know what was the best kind of paper to use with the plane-table, and how it was affected by climatic conditions. In damp climates this was one of the troubles to be contended with in the use of the instrument.

MR. W. P. O'NEILL said he wished to thank the author for the very interesting paper he had given them. It was not often they came across a man who had had such experience with plane-table work. His description of Egypt was very pleasing to them all.

There was one thing he would have liked to have heard from the author, apart from the scientific aspect, and that was—what the cost of these surveys were, what was the saving in comparison to the large trigonometrical surveys, filling in with the plane-table afterwards. He would like to know where the saving came in.

At the present time they were very largely commercial engineers, as they were principally advisers to companies and corporations with respect to the spending of money. That to his mind was the position engineers of the present day had to take.

He would be very pleased if the author could give them some information about the cost of the two systems, as he considered that was the most material thing they wished to know.

MR. A. D. PRICE said he would like to associate himself with the vote of thanks that had been proposed to the author. The interesting paper contained one statement which he thought required explanation. Under the heading of " Errors of the Tacheometer " the author said :—" When the staff is not held at right angles to the axis of the instrument the reading is inaccurate ; this can be obviated by having a plummet and string attached to the bottom length of the

staff on one side." It was evident that when the axis of the instrument was inclined from the horizontal the reading on a vertical staff would require an adjustment according to the inclination of the line of sight; but if the staff, instead of being held in a vertical position, was " waved," as in levelling, and the least reading noted, the accurate distance could be directly obtained.

In tacheometer work the staff may also be placed in a horizontal position, at right angles to the vertical axis of the instrument, the advantage of such an arrangement being the convenience of fixing the staff in position by supports at each end—a spirit level being attached to the side of the staff, and an optical square being employed to adjust it at right angles to the line of sight.

MR. DILLON, in reply, said he wished to express his thanks to the members of the Institution for the way in which they had received his paper. He did not deal with the theory nor the numerous different methods and instruments used in plane-table surveys, which information can be obtained from the several treatises that have been published on the subject on the Continent and also in this country, but merely related the method adopted by him in Egypt.

With regard to Professor Lilly's remarks he agreed that the plane-table is not an instrument of great accuracy in itself, but if used in conjunction with points that have been accurately fixed by other means, such as triangulated points in a trigonometrical survey which formed the basis of the plane-table surveys of India, the Sinai peninsula, and other places, or points that have been fixed by astronomical and azimuthal observations, as in the Nile Valley and Western Oases surveys, described by the author, a fairly accurate map can be obtained, because errors that may arise in the plane-table work are eliminated at those points, and thus prevented from accumulating.

He was much interested in the instrument which Professors Alexander and Lilly are bringing out, and hoped it would prove a success ; at the same time he thought that the number of stations would not be reduced thereby, as places at which the plane-table has to be set up for sketching in details are usually in excess of those required for fixing the principal points, though it would undoubtedly be of great assistance to the surveyor if points inaccessible to the tacheòmeter could be fixed from one station. Any good quality of cloth-mounted paper, with medium surface, is suitable for use on the plane-table, but he did not know of any that could be used if exposed to rain.

In reply to Mr. O'Neill he regretted not being able to give him the information asked for *re* cost of these surveys, and it would be a matter of some difficulty to calculate, as the topographical and geological work were done in conjunction. He had no hesitation, however, in saying that the cost of conducting the survey of the Nile Valley as carried out would be much less than if a series of main and secondary triangulations were first made and details afterwards put in by a plane-table. In point of accuracy of course the latter method, which is adopted by the Great Indian Geodetic Survey, is far superior, but again the time required for such a survey would be much greater. He had completed the Shellal-Korosko survey (Nile Valley), 37 sheets—similar to those exhibited*—in well under 4 months. It would take almost that time to make the necessary main and secondary triangulations and plot them.

In reply to Mr. A. D. Price, it could be seen that the statement quoted by him from the paragraph under the heading of "Tacheometer Errors," referred to horizontal readings, as the second part of the paragraph explained how the readings taken with axis of instrument inclined to the

* See reduced scale map. Plate III.

horizontal were corrected for a vertical staff. With regard to waving the staff for elevated tacheometer readings, he considered this practice would be objectionable for several reasons under the conditions in which he was working in Egypt— viz., employing untrained native staff-men, and encountering much difficulty from the glare and the shimmering of the atmosphere near the ground, produced by the great heat of the sun, though under other circumstances the suggestion no doubt would be found useful.

MR. JOHN H. RYAN, President, in the Chair.

The following candidates were balloted for and duly elected :—

THOMAS HENRY PILKINGTON and ALFRED TUDOR MAC-DERMOTT, as Members.

THE DESIGN OF PLATE GIRDERS.

By WALTER ELSWORTHY LILLY, Member.

(Plates IV. to X.).

THE application of theoretical principles to the design of plate girders does not admit of such accurate solution as in the case of triangulated girders, where the stresses in the various members can be determined with some measure of certainty. In plate girders, the design of the web depends upon assuming certain hypothetical conditions that are supposed to exist, and from which rough and ready rules, more or less based upon experience, have been deduced. These are of a very approximate kind, so much so that it would seem of late years that engineers have been led to provide an excess of material in this part of the girder.

That such provision is unnecessary is evident from the fact that many of the old plate girders, designed and built years ago, with the webs and scantlings much thinner than would be tolerated now, have stood and done their work without exhibiting signs of failure. Such girders as occur in Brunel's Saltash and Chepstow bridges, and other examples given in Humber's "Iron Bridge Construction," may be adduced as evidence of this.

There seems to be little doubt that a retrograde movement has taken place in the design of plate girders, when so much heavier scantlings are used at the present time, when better materials and workmanship are at hand than the earlier engineers had to deal with.

The treatment of the design of plate girders as put forward in this paper differs considerably from that usually given in engineering treatises on the subject, some new rules being given, which it is hoped will prove serviceable.

The results of the investigation show conclusively the advantage of the plate girder for much larger spans than are common at present, and, when properly designed, it seems as if the plate girder would rival the triangulated girder, both in economy of material and cost of production.

A plate girder, for the purposes of this investigation, may be looked upon as a compound structure, in which the load is transmitted to the abutments, partly as a triangulated or lattice girder, and partly as a plate girder pure and simple, and by combining these two together the strength of the girder as a whole is obtained.

Let us suppose a girder made up of a web plate and stiffeners, as in Fig. 4, and carrying a uniformly distributed load, which is transmitted to the girder at a number of points directly under the stiffeners, placed at equal distances apart, such as W_1 W_2, &c. ; if the stiffeners are considered to act as struts and the web to be made up of a series of ties, somewhat as shown by the dotted lines, the girder could then be considered to carry the load much in the same way as in a lattice girder. The tension, acting along these ties, owing to their being of considerable breadth, would give rise to a bending of the flanges round the points of support—in this case the ends of the struts ; the wavy line shows in an exaggerated way the effect of this bending on the flanges.

The diagram of Fig. 4 will give a sufficiently clear idea of the analysis, and the breadths of the various parts of the web concerned in transmitting the load to the struts, when the struts and ties are inclined at 45° ; and the diagram on Fig. 6 when the ties are at 45°, and the struts vertical. The part played by the stiffeners in a plate girder has been, to a large extent, ignored by most writers. and their disposition in the

ordinary type of girder a matter of chance, the web having, as a rule, been assumed to transmit the load to the abutments, and the stiffeners only to have had the effect of stiffening the web and to have played no part in transmitting the load. Considered, however, as a lattice girder the stiffeners act as struts, and have a definite duty to perform, and must be designed accordingly. In Fig. 4 the ties and struts are shown sloping at 45° to the vertical ; there are several reasons why this angle is the correct one.

From theoretical considerations the lines of stress in a rectangular beam can be shown to cross the neutral axis at 45° ; and further, by making the beam into a girder with flanges and a web, that the lines of stress are more or less inclined at 45° throughout the region of the web.

The experiments carried out on the large model of the Britannia Tubular Bridge* show that the lines of stress were approximately at 45°, also that the sides of the girder were drawn into waves along these lines. The deductions obtained from these experiments—the most complete of their kind ever made—show that the stress in such girders are partly as if transmitted by a lattice girder.

From the examination of old plate girders, with vertical stiffeners, the rivet holes connecting the web to the angle irons of the flanges invariably elongate along a line inclined at 45° to the vertical.

The design of the triangulated girder leads to the result that 45° is the most economical angle for the ties and struts to be inclined at, hence, from the principle of least work, it is to be expected that under the action of the load the web of the girder would strain along these lines in preference to any other.

If a girder is loaded in any manner with w lbs. per foot, the shearing force at any section $= \int w dx$, x being the variable measured along the span of the girder, and the bending

* Clark on the Britannia and Conway Tubular Bridges, pp. 181–183.

moment $M = \int F dx = \int\int w dx^2$. Consider now a girder carrying a uniformly distributed load, and for which the load, shearing and bending moment diagrams are shown in Figs. 1, 2, 3. The construction of these diagrams, and the method by which they are obtained, is fully dealt with in Alexander and Thomson's Applied Mechanics.

Taking the centre of the girder as the origin of the co-ordinates, it is evident that the shearing force is proportional to the distance from the origin, and that the bending moment is proportional to the ordinates of the parabola.

Now, the girder is considered to be of the lattice type, with the bracing at 45°. If any section is taken, as at A, the shearing force at that section is known, and is equal to the ordinate of the shearing force diagram on the line of section produced. This shearing force is taken up by the inclined pull on the web and the thrust on the struts, the value of the pull P on the ties $= F_1$ sec. θ, and the thrust T on the struts $= F_2$ sec. θ, where $F_1 + F_2 = F$ the shearing force at that section, and θ = the angle of inclination of the ties and struts, and no matter what type of girder is adopted this relation is always true that the shearing force F at any section is given from the shearing force diagram. To determine the values of F_1 and F_2 some assumptions must be made as to the distribution of the load. In Fig. 4 one-half of the loads w_1 w_2, &c., are supposed to be carried by means of the inclined ties of the web, and the other half transmitted to the upper ends of the struts through the web; the value of the loads at the various points, in terms of one-quarter of the load w, are shown in Fig. 4, and from which the pull on the ties and the thrust on the struts can be obtained from the equation $P = F_1$ sec. θ and $T = F_2$ sec. θ; the value of θ is 45° and its secant $= \sqrt{2}$, hence by multiplying the figures on the diagram by $\sqrt{2}$ the value of the stresses are obtained.

The transmission of the loads from the points of support to

the upper ends of the struts requires a small addition to the thickness of the web which can easily be calculated.

So far the analysis has proceeded on the well known lines usual in investigating the stresses in triangulated girders, the notion of the stress on the ties causing the bending on the booms when transmitting the loads to the struts taking the place of the usual assumption that the forces pass through a point in the joint of the girder.

The second part of the problem deals with the plate girder pure and simple shown in Fig. 5. How is the load transmitted through the plate and what assumptions must be made ?

Consider such a girder loaded with a uniform load, the shearing force and bending moment diagrams will be as in Figs. 2, 3. Under the action of the load the web has a double duty to perform in transmitting thrust and tension. As already remarked, from theoretical considerations, these lines of stress range from 45° to the vertical on either side of the centre line, rapidly changing their inclinations in the central region of the web somewhat as shown ; knowing the direction of the lines of stress and the magnitude of the stress an approximate calculation can be made of the required thickness of the web. A strip of the web, such as B B, is taken and treated as a strut carrying a given load, another portion, C C, being designed as a tie ; by making the assumption that the central portion of the web acts as a tie and the outer portion of the web as a strut, and knowing the shearing force at the various sections from the equation $P = F \sec. \theta$, a close approximation to the stresses can be obtained.

Some assumption, however, must be made as to the length of the virtual column of the strip B B ; commonly it is taken as the length of the diagonal B B ; this value is always too great. It was shown in the experiments on the large model of the Britannia Tubular Bridge that the lines of stress were inclined at 45°, the web being subjected to a thrust in one

direction and a pull at right angles to it, and that under the
action of these stresses the web was strained into a series of
waves. The conclusions to be drawn from these experiments
are important, as they show that the columns transmitting
the thrust are of a virtual length, which is the distance apart
of the waves. The reason why the web breaks into waves can
be shown by imagining a column such as shown in Fig. 9
to be pulled by a shear stress. This shear stress is the com-
ponent of the tension at right angles to the thrust, and comes
into play as soon as the plate deflects. It is as if a pull were
applied to a bent column, causing it to take up several waves
instead of one wave, as it would do if left to itself. The
mathematical treatment of the problem is very difficult, and
if solved would probably be of the form of Euler's well-known
equation for columns—viz., $P = \dfrac{\pi^2\,E\,I}{L^2}$, where P is the load,
E Young's modulus of elasticity, I the moment of inertia,
and L the length of the column. Some multiple values of π
taking the place of π in the formula.

For the calculations required for our purpose it is assumed
that the virtual length of the column is equal to the depth of
the girder, and that the ends are free ; as will be seen after-
wards, so small a proportion of the load is carried in this
manner that it introduces little error into the final design.

The problem of the design of a plate girder can now be
attacked, and it will be considered as being made up of a
lattice girder and a web, and by combining these results
the strength of the girder will be determined. It is evident
that the web is ill fitted to withstand a thrust, and that the
metal placed there for that purpose could be better used as
struts ; hence it follows that the best designed girder will be
one in which the stresses are taken up somewhat as in the
lattice girder. It must be noticed that directly a stiffener is
placed on the web of a girder it always tends to act as a strut,

and plays an important part in transmitting the load ; it has been by neglecting the effect of the stiffeners that so much uncertainty has arisen in the design of plate girders. In Fig. 7 a part of the web with the strut is shown of the girder in Fig. 14 ; obviously the metal is placed to better advantage to bear thrust in one direction, and the pull at right angles, than it would be if the T iron strut were taken away and replaced by an equivalent thickness of plate, as in Fig. 8 ; flexure of the plate would certainly take place under the action of the thrust—in other words, the distribution of the metal in the plate is bad when considered as a strut, and the distribution of the metal in Fig. 7 the more efficient. If the struts are not in the direction of the thrust, but, as in Fig. 10, inclined to it, which represents the case when the struts are vertical, one bay of the girder in Fig. 13 being shown, then a large proportion of the thrust is carried by the strut at A owing to the flexure of the plate throwing the load on the ends of the struts ; the stress then becomes resolved, as indicated by the arrows along the strut and boom of the girder, resolution again taking place of the forces at the joints B, C and D respectively, the web parallel to the line B C being put into tension and thrown into waves at right angles to it.

There are two ways of spacing the struts along the web of the girder, whether they are vertical or inclined at 45° or any other angle. One way is to space them at equal intervals, as shown on the left-hand side of Figs. 13, 14; the loads on the struts then vary, and they must be designed accordingly. The other way is to space the struts unequally, as shown on the right-hand side of Figs. 13, 14, and to keep the loads on them equal, and hence the struts of constant section. The author has devised the following method for spacing the struts in this case *:—Divide up the shearing force diagram into a series of equal areas, as shown in Figs. 2, 16, according to the

* See Appendix.

number of struts required, and from the centre of gravity of
each area drop a perpendicular on to the skeleton diagram of
the girder; the spacing of these perpendiculars give the required
position of the struts.

It has been shown that the stress in the web of a plate girder
is a compound one made up of two stresses at right angles to
one another—one a thrust and one a tension.   It will be con
venient to consider each of these separately, and to design the
struts and web accordingly ; for instance, in Fig. 7 it is assumed
that the plates between the T irons takes up the tension, and
the T irons the thrust ; also in Fig. 8 the metal in the centre
of the plate will be supposed to transmit the tension, and the
outside thicknesses of the plate the thrust.   The calculations
are much simplified by doing so, and awkward questions,
such as—" What effect will a tension have upon the strength
of a metal plate which is already transmitting a thrust at
right angles to the tension ? " are avoided.   The splitting up
of the various parts on these lines is quite justifiable, and will
in no case lead to serious error, and it is the only way of
approaching the subject which admits of simple solution.

From the consideration of the foregoing principles, the
problem of the design of a plate girder resolves itself into the
design of a lattice girder in which the web takes the place of
the tension members and the struts the compression members,
inclined at 45°, if the maximum economy of material is to be
obtained.   As an illustration of the application of these
principles in practice the plate girder shown in Fig. 15 has
been designed.   The struts are arranged vertically as being
more in accordance with the usual practice.   The following
are the required data :—Bridge to carry a double line of railway
on two main girders.   Moving load reduced to an equivalent
dead load of 2 tons per foot over each track, this value having
been adopted from the practice usual on some of the railways
of Great Britain.

Dead load has been taken at ·8 tons per foot for one girder and one-half of the total flooring, rails, ballast, &c., this value having been obtained from comparison of similar types of girders of the same span—clear span = 60' 0''; depth = 7' 6''.

The material of the girder is to be of steel, and the working stress 5.5 tons per sq. in. in tension and compression, which is well within the Board of Trade requirements when the moving and dead loads are considered.

The load, shearing and bending moment diagrams with the necessary scales are shown on Figs. 11, 16, 12.

The ordinates to the shearing force diagram give the maximum value of the shearing force at every section as the moving load crosses the girder, together with the uniform dead load.

It is convenient to determine a statical load which will give this shearing force diagram, and this is shown on Fig. 11, and has been derived by the author from the shearing force diagram.* The load diagram is made up as follows of :—

A uniform dead load of w tons per foot.

    ,,   ,,   ,,   one-half the moving load.

A concentrated load of one-quarter the moving load placed at the centre of the span; and

A pair of wedge shaped loads varying from nothing at the centre to a maximum at the ends.

The distance between the points of intersection of the parabolic curves with the base line, on the shearing force diagram, give that portion of the span on which the shearing force changes sign.

The bending moment diagram (Fig. 12) is drawn for the dead and moving loads distributed uniformly over the whole girder, this distribution giving the maximum values of the bending moment at every section of the girder.

In designing the booms of the girder, the effect of the web

* See Appendix.

to resist bending has been ignored, and the radius of gyration has been assumed to be sensibly equal to one-half the depth of the girder.

The bending moment at the centre equals 1,260 ft. tons, and gives 30·5 sq. in. as the sectional area required. The gross section as designed gives 37·5 sq. ins., and after allowing for rivets this reduces to 31 sq. ins. The horizontal lines drawn on the bending moment diagram are marked off at distances proportional to the area of the angle irons and plates respectively, and the lengths of the plates are determined from the length of these lines.

To determine the section of the web, consider the shearing force at any particular section, and assume that it is equally distributed over the area of that portion of the section of the web, the breadth of the strip is $\dfrac{D}{\sqrt{2}}$, and the shear stress is given from the shearing force diagram. This shearing stress gives rise to a tension $T = F \sec \theta = F\sqrt{2}$; hence the thickness of the web is given from the equation—

$$T = fbt = F\sqrt{2}$$

this reduces in this case to

$$t = \cdot004\ F \text{ nearly.}$$

where $f =$ the working stress of the material

$$b = \frac{D}{\sqrt{2}}$$

D = depth of girder

$t =$ thickness of plate

It is to be noted that this shows that the thickness of the web is proportional to the shearing force at the section, or, in other words, to the shearing force diagram, also for a particular girder $D t =$ constant—that is, the volume of the web is theoretically constant, the web being thinner as the depth increases.

The shearing forces at the various sections on Fig. 16 are—

		Tons	t'		$\frac{t''}{32}$	Size chosen
A	=	23	·102	=	3	$\frac{1}{4}$
B	=	38	·152	=	5	$\frac{1}{4}$
C	=	55	·220	=	8	$\frac{5}{16}$
D	=	74	·296	=	10	$\frac{3}{8}$

The theoretical sizes for the web come out so ridiculously thin in the central portion of the girder that it would be im-·possible to make use of them. The sizes chosen are much thicker than necessary for this reason, and are even now much thinner than would be sanctioned by most engineers.

The riveting of the web to the angle irons and at the butt joints demands some consideration. On Fig. 17 a sketch of the riveting for a portion of the web is shown ; the centre lines of the rivets is inclined at 45° to the direction of the stress. When this is the case the rivets can generally be arranged so that the joint is only weakened by one rivet, or by two if the joint of the plate at the butt is also considered. The figure sufficiently indicates the analysis; the rivets are in double shear, and the shear strength has been taken at 4 tons per sq. in.

The design of the struts will now be considered. Two arrangements are shown on Fig. 15 for these—one with the struts spaced equally and of varying section, and the other with the struts spaced unequally and of constant section. The loads on the equally spaced struts are the vertical components of the stresses acting in the web, and will have the same values as already used in designing the web—viz., 23, 38, 55, 74 tons ; the other portion of the shearing force, as scaled from the ordinates produced through the struts on the shearing force diagram, is transmitted by the web and does not come on that particular strut.

To design the struts the Rankine-Gordon formula has been used in the following form :—

$$P = \frac{f\,A}{1-c\left(\dfrac{l}{\rho}\right)^2}$$

where   P = load on strut

A = area of cross section

f = working stress on material

$c = \dfrac{1}{9000}$

$\dfrac{l}{\rho} = \dfrac{\text{length of column}}{\text{radius of gyration}} = 40.$

Let $P = f\,A_1$ where A_1 would be the net area required for a short column. Substituting in the above equation and putting in values, the following relation is obtained for the area of the cross section of the strut :—

$$A = 1\cdot2\ A_1.$$

So long as the ratio $\dfrac{l}{\rho} \leqq 40$ the column will be as strong as or stronger than necessary. The struts on Fig. 15 have been designed on these lines.

The disposition of the struts when the section is constant is obtained from the equal areas shown on the shearing force diagram. The first strut is designed to carry a load proportional to the area of the diagram intercepted at the first strut, which divides the web and flanges into a square. The load on the strut being known, it can be designed; the equal areas then give the number and position of the remaining struts.

In practice the disposition of the struts would depend upon the cross girders or troughing that might be adopted; by making use of the analysis the design of the struts is in all cases a simple matter.

Some provision must be allowed for the bending action booms round the ends of the struts ; in the old type of

plate girder the upper booms were usually of a box section, as if to guard against this. By assuming the booms to be a continuous girder with the struts for the points of support, and loaded with the vertical components of the stresses in the web, an approximate calculation can be made of the moments; the values, however, are very small, and can easily be provided for by adding to the depth of the flanges of the angle irons connecting the web to the booms, or by a small addition to the web itself; in the design a small allowance has been made in both these directions.

Many other conditions have to be allowed for in the design of a plate girder besides those already mentioned, such as the stiffening of the ends to prevent the distortion of the girder sideways. The allowance for this depends upon the workmanship and the strength of the booms to take up the small bending and twisting moments introduced; it is generally allowed for by bringing one plate of the booms together with the angle irons round the ends of the girder, and to which the connections should be strongly made; the greater the depth of the girder the more necessary is it to make provision against the girder distorting in this manner.

The strength of the upper boom considered as a strut must also be allowed for. The thrust at the centre is known and gradually decreases to nothing at the ends, as is evident from the bending moment diagram; in such a case the virtual length of the column is* ·7 L, where L = length of girder. Also, in estimating the strength of the boom at a strut, the gross area of the section is to be taken; the holes in the metal being filled up, its strength to compression is practically the same as before the holes were made. By treating the boom as fixed at the ends, and substituting values in the Rankine-Gordon formula, the verification of the strength is easily determined. Treated in this manner the boom is

* See Appendix.

often of not sufficient breadth, which indicates that the factor of safety of this part of the girder is less than it should be. This is one reason why the breadth of the booms in the design are greater than usual.

To allow for wind pressure tending to overturn the girder, this can be done by stiffening some of the struts and rigidly connecting them to the cross girders or troughing, the bending set up in these cross connections resisting the tendency of the girder to overturn ; or by stiffening the struts at the end of the girder and extending the breadth of the bearing area, as shown on Fig. 15, the same object may be effected.

In conclusion, the author is of opinion that many of the plate girders of the future will be compound structures, in which the central portion of the girders will be built with triangulated or lattice bracing, and the ends as plate girders with suitable struts, the spans of such girders being far greater than at present. The material of such girders would be distributed to the best advantage, and the cost of construction would be considerably less than in the case of the ordinary braced girder. As an example the design in Fig. 18 has been prepared ; full particulars of the data and dimensions are given for reference on the drawing, which the author hopes will be of service to the profession.

APPENDIX.

SPACING OF STRUTS.

To space the struts so that the load on each strut is the same can be shown as follows :—Imagine a plate girder, as in Fig. 18, with a large number of ribs spaced close together, on either side of the web, so as to form a ribbed plate. The analysis of the stresses in such a girder would closely approximate to the case of the plate girder in Fig. 4.

Now, it has been shown that at any section, the shearing force at that section is proportional to the ordinate drawn through the shearing force diagram corresponding to that section, as A A in Figs. 2, 4; hence, in such a ribbed girder the area of the cross section is proportional to the ordinates of the shearing force diagram, also if a horizontal section be taken, as in Fig. 18, its area would vary point by point similarly to the shearing force diagram. The increasing area could be allowed for in two ways so far as the ribs are concerned, either by increasing their width and thickness, or by spacing them closer together. Now, suppose the ribs are kept of constant section and the shearing force to vary, the number of ribs required at any section would then vary in exactly the same proportion, or, stated in other words, the number of ribs required per unit length along the girder would be proportional to the area of the shearing force diagram per unit of length. From this it follows at once, by dividing up the shearing force diagram into a series of equal areas by lines perpendicular to the base, that the required number and distribution of the struts is obtained.

EQUIVALENT LENGTH OF BOOM.

The value of $\dfrac{L}{\sqrt{2}} = \cdot 7$ L nearly has been obtained as follows:—

Let the girder be loaded with a uniform load over the whole span. The bending moment and shearing force diagrams will be as in Figs. 2, 3. The thrust on the boom at any section is proportional to the ordinates of the bending moment diagram since the depth of the girder is constant, or, in other words, to the area of the shearing force diagram, since $M = \int F\, dx$.

If the shearing force diagram is divided up into a number of small areas, and loads proportional to these areas be applied to a number of struts whose lengths are proportional to the distance of these areas from the centre of the boom, then the problem would resolve itself into the determination of the sectional area required by the sum of the number of struts carrying the varying loads.

Using the Rankine-Gordon formula in the form—

$$P \left\{ 1 + a\left(\frac{l}{\rho}\right)^2 \right\} = f\,A,$$

and keeping the radius of gyration constant for all values of the lengths, then the required summation would be of the form—

$$P_0 + \frac{a}{\rho^2} P_0 l_0^{\,2} = f A_0$$

$$P_1 + \frac{a}{\rho^2} P_1 l_1^{\,2} = f A_1$$

$$P_2 + \frac{a}{\rho^2} P_2 l_2^{\,2} = f A_2,\ \&c.$$

or
$$\Sigma P + \frac{a}{\rho^2} \Sigma P l^2 = f \Sigma A.$$

but $\Sigma P = Q$ the thrust at the centre of the boom, and $\Sigma A =$ area of the section. It only remains to determine the value of the $\Sigma P l^2$, which can be done as follows :—

Let ydx be the small thrust on the length of a strut $2x$, then the summation can be expressed as—

$$=4\int x^2 ydx \qquad\qquad \text{and } y=ax.$$

$$=4a\int_0^{\frac{L}{2}} x^3 dx$$

$$=\left[ax^4\right]_0^{\frac{L}{2}} \qquad \text{but from the diagram } Q=\frac{ax^2}{2}$$

$$=\frac{QL^2}{2} \qquad\qquad \text{and } x^2=\frac{L}{4},$$

hence the equivalent length $=\dfrac{L}{\sqrt{2}}=\cdot 7\ L.$

LOAD DIAGRAM.

The load diagram on Fig. 19 may be deduced from the shearing force diagram as follows :—

From the point C on the parabolic curve at the centre of the span draw a tangent CE and a straight line CF parallel to DB, the boundary line of the shearing force diagram for the dead load.

The portion of the shearing force diagram ACBJ is now made up of a parallelogram DCFB, two triangles EFC and DJB, and the area betwen the curve AC and the straight line EC. Since ACH is a parabola inscribed in the parallelogram ADHG and BH = BD, BC = $\frac{1}{4}$ AD ; also from similar triangles NB = $\frac{1}{2}$ AD, hence BC = NC = AE = FD = $\frac{1}{4}$ AD.

Now, the triangle DBJ is one-half of the shearing force diagram for the uniform dead load on the girder, and JD to scale = $\frac{1}{2}$ dead load. The figure ADCB is one-half the shearing force diagram for the moving load, and AD to scale = $\frac{1}{2}$ moving load and AE = FD = $\frac{1}{8}$ moving load. Hence the parallelogram FDCB is the shearing force diagram for a concentrated load of $\frac{1}{8}$ moving load placed at the centre of the span, the length FEC the shearing force diagram for a uniform load of $\frac{1}{4}$ moving load, since EF = $\frac{1}{2}$ AD ; and the

figure AEC the shearing force diagram for a wedge-shaped load of $\frac{1}{8}$ moving load, the distribution of the load being proportional to its distance from the centre of the span.

` The values obtained above relate only to the loads on one half the girder; for the whole span the values are as given in the text.

The PRESIDENT (Mr. J. H. Ryan) said he was sure they would all join him in according a very hearty vote of thanks to the author for his very able paper, and also for the very clever diagrams which he had provided. The paper was a very lucid one. In the latter portion the author had dealt with the commercial aspect of the question—that is, the cost of the combined structures, which could be very considerably reduced.

In connection with this result there was also another matter which was coming to the front lately, and which would still further reduce the cost, not only of bridge construction, but of all building constructions where steel came into play—that is, the alloy of nickel with steel. Mr. Osmond, of Paris, in Volume CL. of the Proceedings of the Institution of Civil Engineers, alludes to .the alloys of nickel and steel. With the more extended use of steel for building operations and bridges a great field was open for the nickel steel process, by which a working load of 64 per cent. could be obtained, and this was sufficient for all ordinary purposes.

MR. WISE said the paper was an exceedingly interesting one, and he was sorry he had not an opportunity of reading it over quietly at home.

There were some ideas which were very interesting. He had some bridges under his supervision which were something similar to the author's design (Fig. 15). They were about the depth given by the author. He had often noticed an unevenness on the top of the booms in these girders.

He thought the idea of the author to have the struts at an angle of 45° instead of vertically would give the girders greater stiffness.

The next time he was constructing girders he would pay attention to the suggestions in the paper.

With regard to the thickness of the web in the old types of girders, these were entirely too thin.

MR. W. P. O'NEILL said the Institution was very much indebted to the author for the very able paper he had read that night. He was very much struck by the clear way the author tried to convey to the members, and particularly the junior members, a clear conception of the various strains that took place in girders.

He considered that was the chief feature of the paper. He had some experience on the Great Eastern Railway some years ago, when they erected girders something similar to the compound design of the author.

With regard to the struts at an angle of 45°, these had been put in thirty years ago, and they were to be seen to-day.

He thought there was a good deal to be said for the author's compound girder, and he believed it was worthy of adoption. He would bear it in mind whenever he was designing girders, but he would not rake the struts. He would put them in as shown in Fig. 15, on the right hand side. He thought in that design the material was adjusted to the very best advantage. He had been putting in a large number of girders and re-constructing old bridges, and that had been his practice up to the present. He did not see any reason to deviate from that. He considered they got the very best value from the material.

With regard to the diagrams given by the author, he had seldom seen any that conveyed so clearly the strains that occur in girders, and he believed they would be of very great benefit to the younger members of the Institution.

MR. W. ROSS considered the web sections were below safe

working dimensions. He suggested that if the girder (Fig. 15) were regarded as a lattice girder in which the upright stiffeners were taken as struts, then a very large width of the web, even supposing that such width could be taken as equivalent to a diagonal tie, would be required to make up the necessary section for such a tie.

The girder (Fig. 15) is supposed to be safe to carry 168 tons uniformly distributed, say 84 tons at one abutment, and, allowing for the loading on the end bay, say 75 tons as the vertical reaction to be taken by end diagonal if the girder be regarded as a lattice girder. At 45° this gives about 110 tons in the diagonal direction. At 5·5 tons per square inch this gives 20 square inches required, or in a plate ·296″ thick, as on page 125, a width of 70 inches, say—allowing for rivet holes—6 feet wide.

In such a thin section in a large railway bridge exposed to rusting on both sides we might fairly add 20 per cent., or, say, 7 feet wide measured in a diagonal direction. This is a large proportion of a total of, say, 10 feet, and also presumes that the whole 7 feet will be uniformly strained.

Again, take the bearing area of the rivets. In the diagonal width of 7 feet there would be, say, 9 feet lineal of riveting at each end, and taking 4 inches pitch, say, 27 rivets, say ¾ inch diameter.

Bearing area = 27 × ¾ × ·296″ = 6 square inches.

As the load is 110 tons this gives 18½ tons per square inch, and this again taken on the supposition that all rivets are equally loaded. A usual limit for bearing pressure is 10 to 12 tons. He thought the above method a fair way of checking the author's conclusions.

MR. DICK said he thought the method the author had introduced of treating the web section as divided into two parts, for purposes of calculation, was entirely new, and he considered it was valuable.

It was generally held that the economical limit of length of plate girders for heavy work was somewhere about 100 feet. There were several reasons for that; one was that as the girder increased in length the booms were increased in width, and the web of boom was in two parts, between which the double ties and the struts were inserted. Hence the structure had to remain of an open character, so as to allow access for painting.

He considered that an angle of 60° might be better than 45° for the struts.

There was a matter not touched upon in the paper, and although it did not affect the principles arrived at by the author, he thought it should receive more consideration than had been the case in the past. He referred to the effect of both impact and fatigue upon the material. Very valuable communications had been appearing lately in the engineering journals on the subject.

With regard to the author's method of riveting the web stiffeners, this was very interesting, and he believed the direction of the stresses in the web had never been adequately dealt with by any other writer.

There was one very strong argument for the use of the plate type in short spans of under 100 feet: the shorter the span the greater the shock when rapidly moving loads came upon it.

MR. MONTGOMERY said that the author was inclined to throw a little doubt on the economy of some of the work of their present-day engineers when he said there was a retrograde movement in the designing of plate girders with thicker webs than those used by Brunel and others of that generation.

He considered that as these girders were chiefly used in railway works, and that as the load on the driving axle of locomotives had in recent years increased by 50 per cent. over that which the engineers of the last generation had to

provide for, the increased thickness of web was not a retrograde movement, but one designed to provide for the increased weights to be carried.

MR. LILLY, in reply, said he was very much obliged for the kind way in which the members had criticised the paper, and the several points he had brought forward, but he was sorry the discussion had not turned more on some of the original work that had been put in the paper.

There was one thing he should say before starting to reply, and that was, that the shearing force diagrams, and the work in connection with them, had been the work of Professor Alexander. He thought it was only due to him to make an acknowledgment of the fact.

With regard to the remarks of Mr. Wise about the effect of the unevenness of the booms in girders similar to Fig. 15, this was a practical proof that the straining of such girders was on the lines indicated in the paper, and that the analysis was fairly correct.

Mr. Wise had made some remarks about the stiffness of the girder depending upon the depth. If they wanted them very stiff they made them deep, but if they were deep the web became very thin and a compromise had to be adopted. The tendency of the American engineer was to reduce the depths of his girders, but with English engineers the tendency was to increase the depth. He thought in future there would be a desire to increase the depth of plate girders.

Mr. O'Neill had been kind enough to remark on the clearness of the diagrams. He had been assisted by some of the students of the Engineering School in their preparation, and his thanks were due to them for the help so freely given.

With regard to the design for a compound girder which Mr. O'Neill had commended, he thought it was novel, and it was a type which would lend itself to large spans ; and for

cheapness of construction and economy of material he thought it could not be beaten.

Mr. Dick's criticisms on the various points raised in the paper had interested him. He did not agree with him that it was necessary to make plate girders of large span of box section. He considered a single web with well-designed struts to the booms to be all that was required for spans up to 100 feet; for spans varying from 80 to 150 feet he would recommend the design shown for the compound girder. The angle of the struts had been given at 45°. The analysis of triangulated girders led to the result that 60° gave the greatest economy of material. Such analysis did not apply to lattice and plate girders. He was of the opinion that for such girders the most economical angle for the strut was 45°. It was, however, difficult to give a rigid proof of this.

The effect of alternating stress and impact had been purposely omitted, as it would have unduly extended the paper. He hoped to deal with it on some future occasion.

Mr. W. Ross had made some remarks on the calculations, and given what he considered a fair way of checking the author's conclusions. Unfortunately, Mr. Ross had made a mistake in assuming the web in the end bay was ·296 inch thick; the size chosen was $\frac{3}{8}$-inch, which was some 20 per cent. thicker than the theoretical size, ·296 inch. The values taken by Mr. Ross for the loads and the stress on the tie were a little in excess of what he had taken, but he could not agree with Mr. Ross adding 20 per cent. to the plate, and then assuming it was distributed over 7 feet; the breadth over which the stress was distributed was 7 feet 6 inches $\times \sqrt{2} =$ 5 feet 4 inches nearly. The stress was not uniformly distributed on the diagonal tie, but it could be assumed that there was not much variation, and an allowance of 20 per cent. to the theoretical thickness surely made enough provision for that and rivets too.

On Fig. 17 he had shown the manner in which the rivets were to be pitched, and the result would be somewhere about twice as many rivets as Mr. Ross had given and would come out well under the limits for bearing pressure given by him. He was of the opinion that the number of rivets connecting the web to the angle irons in the majority of plate girders was nothing like sufficient, and he was strengthened in his opinion from the examination of old plate girders, which showed the rivet holes worn into an elliptical shape, showing plainly that the bearing area had been too great. He was pleased to hear Mr. Ross's remarks, and to note that his values so nearly agreed with his own.

Mr. Montgomery had referred to the increased axle loads of the present day, and considered the increased thickness of the webs of plate girders were justified. He had considered the matter and taken a value of the live load which allowed for present-day practice; the floors and cross girders certainly required to be thicker than of the earlier days, but he could not agree with putting in webs which showed no justification from theory.

In conclusion, he was pleased with the interest that had been taken in the paper, and to the members for their criticisms.

———

DR. BINDON STONEY observed, through the Hon. Secretary, that plate webs in girders of moderate size, though perhaps not so economical in theory as braced or open-work webs, had certain practical advantages which rendered their adoption desirable. This especially applied to such shallow girders as rolled steel beams, which a manufacturer could turn out much cheaper than if they were built up of plates and angle steel with diagonal bracing and riveted connections. It can be easily shown that a continuous web in girders with flanges of equal area does theoretically as much duty in aid of the flanges as if one-sixth of the web were added to each flange and the web

were made of bracing* and there can be little doubt that rolled beams derive a considerable share of their strength from this cause. It is not, however, prudent to reckon on so great a proportion of the web assisting the flanges of deep plate girders, but it is generally safe to assume in such girders that a certain depth of the plate web, say from 9 to 15 inches deep next each flange, depending mainly on the thickness of the web, may be reckoned as a portion of the available flange area. One practical advantage which shallow plate girders often have over braced ones is that they are more easily scraped and painted and have fewer pockets in which damp can lodge. Hence plate girders are well suited for architectural purposes and for the cross girders of bridges.

The theoretic thickness of a plate web near the ends of large girders and also in short girders which carry heavy weights, such as those of a powerful crab winch, is generally not far from what practical considerations demand, and there is therefore less waste in the plate webs of such girders than might at first sight be supposed. Practical considerations and the necessity for durability, especially when a girder is near sea-water, and therefore liable to corrosion, or in a place where it is inaccessible for maintenance and painting, make it prudent to adopt thicker plates than abstract theory alone demands ; moreover, though thinner plates might be used near the centre and heavier ones towards the ends of a plate girder, this will seldom be found economical, as a contractor will expect to be paid more per ton for a great variety of scantlings than for a few types, and consequently it may be cheaper to have a little superfluous material than go to the nicety of sizes that theory suggests. Formerly it was common practice to place the vertical stiffeners of plate girders over the joints of plate webs, and sometimes to make them of T iron so as to act

* Theory of Stresses, p. 80.

as covers for the joints of the plates and thus economise material; but this practice is less desirable now that plates can be got of much greater size than formerly, and it does not always make a sufficiently strong joint for the plates when the latter require double-riveting at their vertical joints. Diagonal stiffeners are seldom used—first, because their length is about one and a half times greater than the depth of the girder, and this, of course, renders each stiffener much less rigid to sustain thrust in its capacity as a pillar; and secondly, because the connections are not so convenient, especially if the stiffener has to cross the vertical joints of the plates.

Theoretically, the most economical angle for the diagonals of vertical and diagonal bracing, sometimes called quad-rangular bracing, is 55°,* and hence it would appear that this should determine the spacing apart of the vertical stiffeners of plate webs, so as to spread them a little further asunder than the depth of the girder, and make rectangular in place of square panels. Bringing the verticals close together, however, enables a larger share of the plate web to be put into tension for diagonal stresses, and this must be taken into account when designing any particular girder. One advantage of bracing, especially in large girders, is that bracing lends itself to the use of deeper girders than is generally permissible with place webs, and this, of course, reduces the amount of material required for flange stresses.

In the office, rough and ready methods that save time and labour often supersede more recondite calculations, and it is generally desirable to avoid integrals or the higher mathe-matics when dealing with the average engineer or the draughtsman designer. The following will be found a rapid and fairly accurate method of calculating the stresses in a plate girder, and it may be readily worked out while sitting

* Theory of Stresses, p. 238.

at one's writing-desk with a pen and ink sketch, not necessarily drawn to scale. It will be illustrated by an example, as this is simpler than a general description :—

Let the skeleton diagram (Plate X.) represent one-half of a plate girder loaded uniformly and with vertical stiffeners spaced so as to form square panels. Let the uniform load be supposed concentrated into equal weights, W, each weight representing the load supported by one bay of the flange, either top or bottom as the case may be, and resting either on the top, or suspended from the foot of the verticals. In this example the load is supposed to rest on the top flange as would be the case in a railway bridge with a deck-platform and rails above the girders. The load over the last vertical—namely that resting on the abutment—is only $\frac{W}{2}$, as it represents the uniform load which is supported by the end half-bay.

The shearing stress or thrust on the first
vertical next the centre   ..   = 1 W.
On the second vertical ..   ..   = 2 W.
On the third vertical ..   ..   = 3 W.
On the fourth vertical ..   ..   = 4 W.
On the fifth or end vertical   ..   = 4½ W.

The sign + written before a stress in the diagram signifies that it is compressive, the sign — that it is tensile.

As the panels are square the tensile diagonal stress (diagonal component of the downward thrust in the verticals), starting from the foot of the first vertical next the centre to the top of the second vertical, is at an angle of 45°, as represented in direction by the dotted diagonal. Consequently the horizontal component or flange stress given off at the top of this second vertical, tending to thrust the top flange towards the centre =W; that is, it equals the downward thrust or shearing stress at the first vertical. In the same way the horizontal component or *increment* of flange stress at the top of each successive

vertical equals the downward thrust or shearing stress passing through the previous vertical on the side next the centre. These increments are written in the diagram along the centres of the successive bays of the top flange. Then, in an upper line, add up these successive increments so as to get the actual gross stresses in each bay. Do the same for the lower flange. Generally, we need not trouble about the stresses in the web, as the thickness of the latter is almost always more than sufficient to take the diagonal stress. However, the stresses are easily calculated, recollecting that the length of the diagonal of a square is 1·414 times the length of its side, and consequently the tensile stress in each successive diagonal = the downward thrust or shearing stress in the previous vertical multiplied by 1·414.

We now have all the stress elements necessary to make a first rough design and estimate of the girder, and even though the distance of the verticals apart may be altered in the finished design, this will not materially affect the quantity of material in the flanges or web, or affect the estimate of cost. One practical advantage connected with this method of calculating the stresses in plate girders is that it enables the engineer to see quickly whether his rivet area connecting the web and verticals to the flanges and to each other is sufficient. This is especially important when plate girders have to carry extra heavy loads, such as a hundred-ton crab winch.

The available widths of the plate web that effectively take up the diagonal tensile resultants of the thrust or shearing stress passing down to the foot of the previous vertical will probably not extend much more than from 12 to 18 inches on each side of the foot of the axis of the vertical, but it must not be supposed that all the rest of the web is quite useless. Besides aiding, as has been stated, the flanges to some degree, it stiffens them against vertical movements, and, of course, keeps the verticals from bending in the plane

of the web, and also it adds to their available cross section to sustain vertical thrust, just in the same way that the web assists the flanges to sustain horizontal stress. It seems probable that a width of the plate web of from 9 to 12 inches on each side of the axis of each vertical may be calculated on for taking thrusts, provided the stiffeners project so far at right angles to the plane of the web as to prevent them from deflecting at right angles to the plane of the girder.

There is some reason for supposing that the shearing stress in plate girders acts with greatest intensity in the neighbour-hood of the neutral surface, but this is too elaborate a matter to suit the present discussion, and those who wish to go into the question are referred to page 494, "Theory of Stresses." There seems good reason for supposing that a piece of iron or steel is not injured by both tensile and compressive stresses being transmitted through it simultaneously at an angle with each other, especially within the limits of stress that are usual in practice. For example, experiments on the strength of riveted joints have not indicated any weakness in the plates other than that due to the reduction of area by the rivet holes or the mode of punching, and if moderate compression did reduce tensile strength, closely riveted joints, such as those of boilers, would be weakened by the contraction of the rivets in cooling, which squeezes the plates at right angles to their plane, but there is no indication of this in practice. Also, in experiments on the tensile strength of iron and steel, the ends of the sample are generally grasped by powerful grips which compress them sufficiently to prevent slipping and the sample seldom breaks where thus com-pressed, as rupture usually occurs at some intermediate point between the gripped ends.

Mr. Robert Cochrane, Vice-President, in the Chair.

The following candidates were balloted for and duly elected, viz. :—

George Charles Vincent Holmes, as Member ; and Thomas J. O'Neill, as Associate Member.

The Youghal Foreshore Protection Works ; and Deep Sea Erosion on the East Coast of England.

By R. G. Allanson-Winn, Member,

(Plates XI. to XX.).

Having had the Youghal foreshore under close observation since 1898, the author hopes that a short description of the methods adopted to combat the sea's encroachment may be of some interest at the present time. For many years previously the condition of the foreshore—especially that portion which lies to the west of Clay Castle—had been such as to cause considerable anxiety, and, in the summer of 1899, the apprehension reached such a point that all parties interested came to the conclusion that something should be done. The author was called in to advise, and, having met the Chairman and other members of the Town Council on the shore, indicated the points where breaches were very likely to be made in the event of a concurrence of high tides and gales.

It should be mentioned that at Youghal there exists no heavy and well-defined shingle bank, though there is a considerable percentage of shingle brought up from the sea bottom during very severe weather, when the wind is blowing from the east or south. The " full," or highest ridge, consisted of sand and shingle in the proportion of perhaps 10 to 1. The top of this full was about 3 feet above the highest spring

tides, and the whole mass lay on the surface of bog.   It would be hard to imagine material which would offer less resistance to the action of running water.   The small initial channels, through which the surface water had already made its way, were plainly visible through the top of the highest level of this flat sand and shingle bank, and it hardly needed an expert's eye to detect the danger of an immediate inundation of some 600 acres of low-lying land, through which the G. S. & W. Railway runs on its entrance to the Youghal terminus.

Having verbally explained the situation to the Town Council, and suggested the remedy, the author wrote in June, 1899 :—" Without wishing to be an alarmist, I have no hesitation in saying that if immediate steps are not taken those interested in Youghal run a grave risk of sustaining losses which may be as sudden as they will be serious.   ' A stitch in time saves nine,' and where the remedy is economical and effective it is a pity not to apply it."

It was very evident that the encroachment, when it did take place, would result in the immediate submersion of the 600 acres of land, all of which lies below high water level, and, this being the case, the entire area would be added to the sea at one blow instead of, as is usually the case, strip by strip over a series of years.   Notwithstanding the author's representation nothing was done because of the dispute between the interested parties as to what proportion of the cost should be borne by each.

Some months previously—i.e., towards the end of 1898, or commencement of 1899—the author had explained to Mr. Bayley and Mr. Gordon, the G. S. & W. Railway Co. Engineers, the advantages which would accrue by applying the Case System to Youghal, and both those gentlemen were subsequently much impressed by an inspection they made, in conjunction with the late Mr. Edward Case and the author, of the work at Dymchurch and Deal.

K

There were no fewer than six interests involved, viz. :—
(1) the County ; (2) the Town of Youghal ; (3) the Railway
Company ; (4) the Local Landowners ; (5) the Owners of
House Property ; (6) the Government, for the protection of
the rifle range. It was never expected that the last three
named would contribute much towards the total sum required,
but it was felt that every little helps, and that when once an
agreement had been arrived at there would be no difficulty
whatsoever about raising the money on easy and satisfactory
terms. The proportions of contributions alone required
settlement. During the period of masterly inactivity which
ensued, whilst the summer of 1899 was turning into autumn,
the sea was not idle, and the author was not very much
surprised one morning—only a few months after his predic-
tion—to hear that the sea had broken through the shingle
bank at the identical spot where he had pointed out the initial
channel to the Town Council, had established a deep channel,
and that every tide rushed in and out widening the gap
perceptibly day by day.

On visiting the place soon after, it was found that the
breach had widened to about 100 feet, that the rush of water
at flow and ebb was considerable, and that someone, with more
confidence than judgment, had endeavoured to close the gap
by throwing in a few bags full of sand or shingle, which were,
of course, promptly washed away. By this time there was a
good deal of excitement amongst the town's folk and others
interested in the prosperity of Youghal, for there was every
chance of the Esplanade being taken in the rear and Clay
Castle becoming an island. This excitement was rendered
the more acute by the report that the waves had washed
into the railway carriages, and that the Company were
contemplating making Killeagh their terminus instead of
Youghal.

That the Company may have entertained such an idea is

not to be wondered at, seeing that their line was then running
alongside an arm of the sea, and was quite unprotected ; but
they did not abandon Youghal ; they came to an understanding
with the other interested parties above enumerated, with the
result that plans and estimate for closing the breach, erecting
17 Case groynes and building a long sluice run for taking off
the surface land water were prepared (Fig. 1).

Procrastination, that worst enemy to economy, had, so to
speak, left its mark on the situation, and before the embank-
ment was started in February, 1900, the breach was 500 feet
wide, and resembled the estuary of a fairly large river.

When this embankment, which consists of rows of the best
pitch pine piles, driven in parallel lines and sheet piling and
waling with suitable filling, was finished, it was found that
there was a strong tendency to fresh breaches on both the
eastern and western ends, and the author then ran out
wing-embankments, consisting of double rows of sheet piling,
well braced, and with suitable waling, amply strong enough
to check the surface water, which, *though in itself incapable
of knocking down the lightest wall, is productive of the greatest
mischief by forming initial channels.* Too much stress can
hardly be placed on the importance of *taking shores in time,*
and as soon as these small but unmistakable evidences begin
to show themselves.

They were apparent at Youghal in June, 1899, and had the
advice given been then taken, the cost of the heavy 500 foot
embankment would have been saved ; they are now apparent
at Tramore, where the loss of the racecourse is only a matter
of time if the sea is left to itself ; they must have been strongly
apparent at Ballycottin Bay, where an arm of the sea has been
allowed to establish itself, and is now steadily working its
way over the low-lying land in the direction of Cloyne.

The Youghal work, consisting of the embankment, sluice
and sluice run, and 17 low groynes, averaging 600 feet each,

was finished in 1891, and measured up and handed over in April of that year. It is satisfactory to be able to chronicle that from the moment the groynes began to act there was a perceptible improvement in the shore, the sand came steadily in, and very soon the deep scour, as shown in the photograph (Fig. II.), began to fill in until the shore recovered its pristine condition, and, indeed, far more than that, since low water mark has been driven about 200 feet seaward, and there is an accretion of over 5,000 tons of sand per 100 feet of frontage. At the worst points—*i.e.*, over a distance of some 400 or 500 feet—the author calculates the accumulation as close on 8,500 tons of material per 100 feet. Here the shore has raised in solid sand between 8′ and 9′ in vertical height, and, as will be seen on reference to the photographs (Figs. III. and IV.), and section on AB (Fig. V.), the top of the embankment is barely visible ; more than this, high water mark has now retreated, and the space between it and the embankment is rapidly covering over with weeds, grasses, &c. The contour of the shore is returning, as is shown by the dotted line on the sketch plan (Fig. I.).

Up to the end of 1902, all through the gales of December, the work stood well, and no damage was done to the groynes, though there was an indication of scouring action immediately to the west of Clay Castle.

The 12th of January heralded a succession of gales from the worst quarter. The wind, which had previously blown from the north, then veered round to the south-east, and continued to blow from that quarter with varying force all through the time of the full moon tides. The effect was to pile up an already very high tide to such an extent that heavy waves broke over the embankment and wing walls, and washed out the backing, which was for the most part merely sand and shingle.

In designing the embankment and wing walls it was hoped that the level of the highest points would be sufficiently high

to prevent anything heavier than spray and foam from reaching the back of the structures (Fig. VI.).

One of the greatest advantages claimed for the Case system of groyning is the formation of a gradually sloping shore which shall prevent any considerable volume of water approaching high water mark.   When these groynes have been successfully applied, as they have at Dymchurch and Youghal, it is expected that a very slight embankment at or near high water mark should be sufficient to prevent (1) the water reaching the back of the works; and (2) the shingle or sand being pushed inland.

It seems evident that the Youghal embankment and wing walls were not carried to a sufficiently high level, for on January 15th " the last line of defence," as embankments used in connection with the Case groynes may be called, was so weakened by the washing out of the backing that it gave way at a point at the junction of the main embankment and eastern wing wall (*vide* Plan of Youghal Foreshore and Groynes). This damage occurred during the early hours of the morning of January 15th, and a clean breach of about 80 feet wide was cut through the wing wall, the adjacent portions of the embankment being damaged, and the whole of the wing wall being weakened throughout its entire length (Figs. VII. and VIII.)

When the author inspected on the following morning he found that, as is often the case with sea protection works, the unexpected had happened.   In December he had noted the scour above alluded to, and, fearing damage in the neighbourhood of Clay Castle, had ordered an extension of protective works in that direction.   But the sea did not make any breach near Clay Castle, though considerable volumes of water broke over the wing wall at that point, and rushing down to the lower ground at the back of the embankment helped to scour away the material at the place where the breach was actually formed.

There was no time to be lost in carrying out the repairs, as every tide ran through and both widened and deepened the gap. Gangs of men were arranged for, so that the work might go on night and day, and a double row of sheet piling was run across the gap, as shown on the sections. When this was finished, and a considerable amount of filling had been tipped in, a double row of pitch pine piles was driven. The back row were 9″ × 9″, and the front, 9″ × 6″. These piles were driven parallel to and touching the rows of sheet piling, and at intervals of 9 feet (Figs. VIII. and IX.). Above the sheet piling sleepers were fastened horizontally to the pitch pine piles. The work was commenced on January 19th, and finished on February 6th. It is remarkable that through all the severe weather none of the groynes were damaged, and that they acted so well that, by the commencement of March, most of the sand washed away by the deep scour through the breach had come back again. Indeed the shore has now very nearly recovered its former section, and at the present moment it is hard for a casual observer to see where the damage originally took place.

Notwithstanding the satisfactory carrying through of the repairs, it cannot be denied that the fact that such damage should be possible is both disappointing and discouraging. It shows, for one thing, that we had not allowed a sufficient margin of safety in this particular case, and it brings us face to face with a very difficult set of problems which will present themselves in future works of a similar nature. Given certain conditions, such as range of tide, depth of water and nature of currents in the offing, direction of prevalent winds, &c., can we ever say how many feet the top of an embankment should be taken above H.W.O.S.T. ? Are we to allow a certain margin of safety, and look upon storms which bring about damage as special disasters of the nature of earthquakes or tidal waves, and as such unavoidable; or are we to

endeavour to make more substantial embankments with heavier and better constructed backings ?

No sea walls or groynes would have afforded the slightest protection to Galveston, on the Gulf of Mexico, which only a few years ago was nearly destroyed by a huge tidal wave, and, though we enjoy comparative immunity from such visitations in these latitudes, there are not wanting instances of abnormal tides, which, even unaided by the wind, have topped and destroyed embankments which might—had they been raised to a few feet higher level—have stood safely for an indefinite period.

The question is, of course, one which largely affects the cost of works, whether those works are opposed to the attacks of the open sea, or merely embankments to withstand the pressure of backwaters.

One good distinction may be drawn between *walls* and *embankments*—the former may be left alone with merely nominal expenditure on maintenance, whilst the latter must be constantly watched, and an annual sum be set aside for maintenance. Of course, accidents will sometimes happen, even to the best sea walls, but when the works are really first-rate and substantial such accidents are extremely rare. Clay or marl banks faced with stone are (when unsupported by groynes) quite unsuited for situations exposed to the action of the open sea, though they are frequently used in backwaters where there is not much wave action. Even in the case of backwater embankments a careful watch should be kept, especially during high spring tides ; for unless the top of the bank has been taken many feet above the level of the highest possible tide, there is still always a danger of the continuance of a special direction of wind together with a very high tide so heaping up the water that the embankment may be topped. When this is the case, those in charge of the maintenance should watch with the greatest care for any sign of a stream

of water finding its way over the top of the bank. The moment such sign is detected, gangs of men with all the appliances and material available, should be put on regardless of expense to check the mischief *in its initial stage*. If any considerable volume of water once establishes itself in the form of a stream, even only a few inches deep, the back portion of the embankment, which has not probably been so carefully faced as the sea face, may be rapidly torn out, and a breach be established in a wonderfully short space of time. A highly instructive example is furnished by the embankment built at Glenbeigh, Co. Kerry, by the then Lord Headley in the early part of the 19th century (Figs. X. and XI.). The late John Wiggins,* F.G.S., after describing the many improvements carried out in that then wild and lawless region by his Lordship, who was regarded as one of the most improving and benevolent landlords in the country, goes on to say that, in order to reduce certain arrears of rent which had accrued in consequence of the depression of prices and general bad times in the years 1815 and 1816, it was decided to commence an embankment to shut out the sea from about 400 acres on the coast, which seemed a fit subject for intake :—" Many difficulties presented themselves in this undertaking. The course of the Beigh, a rapid river, subject to sudden and violent floods, was to be changed. The sea wall was to be built across a sand-bank, very unsound in some places, and intersected by several deep shifting channels. The tide‧flowed deep and rapid, and the mountain waters poured down suddenly over the space to be enclosed. No other means were to be employed than the labour of the people, or any other materials than those the place afforded. . . . The attempt was a novelty in that country ; all considered it fraught with extreme danger, and some as a presumptuous invasion of Neptune's dominions.

* " Report on Three Cases of Successful Improvement of People and Property in Ireland." By John Wiggins, F.G.S. 1836.

But, notwithstanding these formidable obstacles, a sea-wall was constructed which effectually excludes the tide. It is built without a single foot of timber, yet, being made impervious to the water, well secured at the foundation, and protected by ponderous rocks, being also of the most approved form and dimensions, with proper sluices for the land waters, and secured by other requisite precautions, it may be pronounced a safe and permanent work."

For many years after the completion of this embankment the 400 acres of reclaimed land—all of which is alluvial deposit—continued to afford splendid crops, and the grazing was so far-famed that people were in the habit of sending cattle, sheep and horses from long distances, North Kerry, Limerick and Cork, to improve their condition and increase their value. Vast crops of potatoes, oats and hay were raised on this intake, on which a home farm was established, and a regular rotation of cropping was adopted. In the evidence of an expert before the House of Commons Committee on the subject of the Irish poor, 1830, occurs the following :—" I saw land that had formerly owned but the dominion of the sea bearing fine crops of every description ; and I saw a population which, before the exertions of Lord Headley, was little removed from savage, completely housed and clothed, and exhibiting more certain indications of civilisation than are often to be met with in the most fertile and central parts of Ireland."

Very soon after the publication of the work in which Mr. Wiggins wrote of the " safe and permanent " embankment, a very high tide with an easterly wind topped the highest point, and the water, rushing over, tore away the land slope and created a serious breach. This breach was closed by Lord Headley, and one would think that the experience gained would have caused those in charge to exercise the greatest vigilance. Apparently there was not a sufficient watch kept, for a few years later the sea again breached the embankment,

and for nearly 60 years, up to the present date, every tide has swept in and out of that breach, flooding the whole of the land, which is now only valuable to the cockle pickers at low water.

A reference to the plan (Fig. X.), which is taken from the Ordnance Survey, 1898, shows the position of the breach, and the dangerous propinquity of the reclaimable land to the open waters of the broad Atlantic. The repair of the breach and general heightening and strengthening of the embankment is a sufficiently simple matter, involving a little engineering skill and the exercise of a great deal of care. The author estimates the cost at about £6,000, and, as the 400 acres of alluvial land would be worth at least £2 10s. per acre per annum, it will be seen that, if the risk stopped short at the question of integrity of the embankment, the investment would possibly be a very good one. Unfortunately, however, this is not the case, for there is the ever-present danger of direct assault from the turbulent seas of Dingle Bay, which break upon the western shores. So that, though the few Case groynes erected on the shore have done wonders in checking the advance of the open sea, the system has not yet been applied on a sufficiently extended scale to completely safeguard the necessary mile or so of foreshore, and to build an efficient sea-wall to protect this distance would involve an expenditure of over £30,000—a sum far beyond the value of the land.

A rough section of Lord Headley's embankment is shown in Fig. XI., the author's proposed strengthening being indicated by dotted lines. The embankment itself is composed of peat or bog-stuff, rammed tight and cased with stone—the eastern slope being about 1 in 3, and the western 1 in 2, and the whole bank has sunk so much that it is now completely submerged by the highest spring tides. The embankment, which is about 4,000 feet in length, would require an additional

5 feet in height, and a considerable addition of material—
clay and stone—to make it safe. The sites of the sluices
would have to be chosen with care, and the closing of the
breach would be best effected by *layers* of the best masonry,
set in hydraulic cement. The current through the breach,
which is about 150 feet wide, runs with great force, and deep
holes have been scoured out on each side by the flow and ebb
during all these years. The holes are indicated by the crosses
on the plan (Fig. X.). To make this work secure the author
recommends driving two, or even three, rows of stout piles,
9″ × 9″, before commencing the concrete layers, which should
not be raised more than one foot or thereabouts each tide.
It will be observed that this embankment was merely opposed
to the *backwater* of Rossbeigh Creek, and never encountered
heavy seas. The deep holes on each side of the breach are
the result of 60 years of scouring action as the tides have entered
and left the intake, and it is instructive to compare them with
the hole which was so soon scooped out inside the eastern
wing wall of the Youghal embankment by the entrance of
only a few tides through the breach formed in January last
(Figs. VII. and IX.).

DEEP SEA EROSION.

Since writing the above a re-survey of the shore to the
West has been made, and according to the Report dated
March 25th, 1903, the winter storms have made sad havoc
with the coast line, and have still further reduced the chances
of ever reclaiming the intake land. The Report states :—
" On account of the depth of the scour all along this portion
of the shore—the sand having been cut out by the violent
storms of December, 1902, January, 1903, and the exceptional
storm of February 26th and 27th, on the New Moon Tides—
the situation has become very critical, and it would not surprise
me to hear that a permanent channel had been cut through

during any westerly gale on a high tide. . . . Observations all along base line 1 convince me that, whatever material may be collected during the favourable months, a few winter storms scour it all away, and more along with it, so that each time a fresh denudation takes place the sea commences its erosive action where it left off the previous winter ; and so the advance goes on year by year. ,There is moreover a most unfortunate condition which I have always recognised as a source of special danger, and I need hardly say that it makes the question of *wall* protection almost impossible, or, at any rate, enormously expensive : Underlying the cliff and marl is a stratum of fine yellow sand, which is in many places in a running condition, land springs permeating it, and rendering it entirely unstable and shifting."

The property here attacked consists of building land and valuable farms, and there is no doubt that the depth of the erodible material extends to far below low water level, as the foundations of a house, which in 1820 stood in the middle of green fields, are now well out in the offing, and are covered by many feet of water at low tide. This proves that the erosion has taken place below low water level, and we are brought face to face with a set of problems which have not as yet received much attention.

If the question of material used for the backing of embankments, which are only occasionally in jeopardy, is of such importance, how much more serious is that far larger question of the stability of the material upon which we erect our protective works ?

UNTRUSTWORTHY FOUNDATIONS.

The observations at Glenbeigh for a period of over 30 years, and more recent observations on the East Coast of England, convince the author that in treating the shore as a bank low water mark must not be always regarded as the toe of

the bank, which must be sought at the lowest level of the erodible material—possibly 60, 80, or 100 feet lower still. The prevalent idea is that if walls and groynes can be made to stand anywhere between high and low water marks, nothing more is required. In this opinion the author concurred until quite recently, when he propounded the following question :—Can any protective measures taken between high and low water levels arrest that deep water erosion, which is going on in all places where the sea is making a dead set on the land, and *where the material for a considerable depth below low water level* is soft and easily eroded ?

On the coasts of Yorkshire (Holderness), Lincolnshire, Norfolk, Suffolk, and Essex, there are enormous interests— in the aggregate—being now attacked by the rapidly encroaching North Sea. But is there any remedy ?

An examination of the conditions generally obtaining shows that below many of the towns, and much of the valuable agricultural land, the strata consists of glacial drift, sand, boulder clay, laminated clay, and other more or less easily eroded material, for a depth of 100 to 200 feet, and that the encroachment of deep water has steadily gone on ever since the earliest traditions.

For example, there are now the remains of ancient towns and villages between one and two miles from the eastern shores of England, and these remains are to-day from 5 to 6 fathoms below low water level.

An examination of the section, Fig. XII., will explain the situation. The dotted line represents approximately the section which existed many centuries ago, and the other the section of to-day.

Had protective works been started in the old days, any-where between *a* and *b*, would those works have prevented the erosion of soft material between the levels of *b* and *c* ? To-day the problem is the same, for we have still the soft

material below low water level and the sea bottom is now wearing away between b', c', and d', and will continue to wear away in spite of anything we can do between a' and b'.

It cannot be contended that erosion only takes place from high water level downwards, because the contrary is proved by the travel of shingle, &c., from deep water towards the shore in rough weather, and this is independent of any action going on above low water level.

So we see that there are two distinct erosions going on; the one, which is visible, between high and low water marks, and the other, which is invisible, below low water mark, and far down into deep water.

Thus, even if we could deal with the former class of erosion we are powerless to arrest the progress of the latter; at least no system has yet been devised which will stop the formation of deep sea gulches often running parallel to the shore, and it is the tidal and storm action in such submerged channels, as may be found between the Kish Bank and the Dublin and Wicklow shores, or between the Dogger Bank and the east coast of England, that we owe much of the erosion now going on below the lowest level we can protect.

These considerations should be worthy of our careful consideration when we are called upon to design costly walls for situations where we know the substratum to be unsound for a depth we cannot possibly cut down to for our foundations.

TRAVELLING SHINGLE.

During exceptionally severe storms, when the wind is on shore, stones of considerable weight—invariably with long growths of sea-weed attached—are brought in from the deeper water outside. After the south-eastern storms of January the whole of the flat sandy shore of Youghal was literally strewn with stones of all sizes and shapes, which had been carried from the bed of the ocean, chiefly by means of the

heavy growths of sea-weed. Some of these, collected at the time by the author, are now exhibited, as well as some which came in at the time of the gale of Thursday and Friday, the 26th and 27th of February last, and were also picked up on the Youghal shore after the storm.

One of the stones exhibited is over 32 fbs. in weight, and there were others heavier—up to 50 fbs.—brought in by the agency of the storm, aided by the long seaweed attachments, which measured, in many instances, over 6 feet in length.

This matter, though properly forming the subject of another paper, is mentioned incidentally here on account of the importance of accumulations of shingle at places where shingle banks do not exist and where their presence would be advantageous. Several hundreds of tons of shingle were probably moved on to the Youghal shore by the gales of last January, most of it being now buried beneath the sand (Fig. XIII.). It is *only* during exceptionally severe on-shore storms that shingle is thus moved in, and this seems to point to the danger of removing shingle in large quantities and relying on the storms to replace it.

A wide distinction must be drawn between places like Youghal and Dymchurch, where the sea is not making what may be called a "determined attack" on the land, and places such as those described on the east coast of England where the encroachment is steady and relentless, and where the soft material extends to depths far beyond the reach of protective measures.

It is no use blinding ourselves to the existence of this deep-sea erosion. There it is—as shown by the section; it is always going on and we cannot stop it by devices on the visible shore at a higher level.

Local authorities too often consider only what they can see—falling cliffs, wasting beach, and broken down walls, groynes, &c., for which they have paid heavily. They do not

realise that the trouble is brought about mainly by the advance of deep water, and even when this is fully explained and proved they exhibit a tendency to ignore the facts because they are unpleasant ones.

The author believes that this aspect of the foreshore protection problem has never before been prominently advanced, and he trusts that members of the profession will discuss it and give it their closest attention.

The CHAIRMAN said he was sure they felt greatly indebted to Mr. Allanson-Winn for his interesting and instructive paper. It was one of a kind they gladly welcomed, inasmuch as it was a description of works actually carried out and of the results accomplished thereby. For these reasons the paper was one of considerable value to them, and he would be glad to hear the remarks of any member or visitor on it.

MR. R. CLARK said the subject was a very interesting one to geologists as well as engineers, especially to those who had traversed the coast line and studied the material composing its beaches.

The transportation of material ranging from shingle to boulders of considerable weight by the agency of seaweed was explanatory of the occurrence of foreign elements in our beaches, and to geologists had been most useful in defining the ages of some rocks. The great chain of granite hills which extends from Dublin, through Wicklow, to the Blackstairs in Wexford has had its age fixed beyond contention from the finding of blocks of granite in the carboniferous rocks of the district, and these were undoubtedly floated to the deep waters of the carboniferous sea by seaweed. Specimens of calp containing those inclusions can be seen in the Dublin Museum.

Along the coasts of Wicklow and Wexford flints and chalk derived from the Antrim rocks, as well as, amongst others,

pieces of the Scottish rock—" Ailsa Craig "—are met with in abundance, and afford indications of the direction of the currents, as well as the carrying powers of seaweed.

MR. HEWSON, B.L., said he was very much pleased with the paper, which showed that the author was an expert.

In a recent lawsuit he had the assistance of the author, and he attributed his success to the very able manner in which the author gave his evidence under very severe cross-examination.

But he had to confess that the reading of the paper had frightened the life out of him. He never calculated upon this erosion taking place. If this erosion was to take place on the Wicklow coast, then he was afraid it would be good-bye to any protective works whatever.

The only hope he had was that the pier which the Board of Works had erected at Greystones would act as a groyne, that it would be able to catch a large alluvial deposit, and manage to keep the outside shore from moving south.

With reference to the evidence of experts, he thought there should be some arrangement made whereby they would receive proper remuneration for their time. Sometimes when a case was won and it came to the taxing of the costs they found an amount was allowed for an expert that they would not think of giving to a man for sweeping street crossings. He considered a great profession like the engineers should do something to see that their expert members in these cases should be allowed substantial remuneration for their evidence.

MR. DICK said the paper contained a great deal of information which was not a matter of very common knowledge, particularly the part referring to submarine erosion.

He wished that in many places this erosion would take place. In the much-abused Board of Works piers and harbours the

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usual experience was that they had to use dredgers in order
to maintain these places at a sufficient depth.

With regard to the reclaiming of land from the sea, he
thought that the level of land to be reclaimed should never
be lower than about the mean tide level.

He believed that in Ireland land had been reclaimed the
embankments of which were upon ground very much below
the mean tide level, and the cost was, in consequence, out of
all proportion to the subsequent value of the land reclaimed.

Mr. W. Kernaghan said, with regard to " travelling shingle,"
large foreshore protection works are at present in course of
construction at Barnageeragh, between Skerries and Bal-
briggan.

The shingle travels continually, causing considerable
trouble ; in one place the beach seems to have lowered about
4 feet, exposing the toe of the pitching and rendering it neces-
sary to underpin with concrete faced with ashlar.

From what he had heard from the author on the subject
of " Case groynes " he considered the system could, with advan-
tage be applied to the shore at Barnageeragh, and he would be
glad Mr. Winn would pay a visit to the place and give them
the value of his opinion.

Passing to the subject of closing breaches in sea embank-
ments, it is most essential to the safety of the work that
initial currents are stopped in time before they work into
deep cuts. There is very great danger to the embankments
if these are neglected, as the tendency is to scour out channels
on the inner side of the bank, which may subside or fall into
them. He successfully dealt with a case in point by running
out spurs of timber and stones, so as to deflect the current
off the line of embankment.

He might also draw attention to the fact that when the slob
is of certain consistency, as in the case to which he referred, the
cutting action of these initial currents near the outfall can be

stopped or retarded by sloping off smooth the sheer faces of the cuts. When the fringe of the slob near the breach was dealt with in this way the outflow had little or no effect on the smooth sloped surface.

One of the most important problems in the closing of the embankment is the proper length of the tumbling bay or bye-wash. This should be designed of such a length that the greatest head will not much exceed 3 feet.

In a case which came under his knowledge the length of the bye-wash was about 1,000 feet at half tide level, and the following is a table showing the maximum heads on the flood and ebb at spring tides :—

—	H.W.	Hour	L.W.	Hour	Max. Head Flood	Hour	Max. Head Ebb	Hour	Range
Gap open 30 feet below L.W.S.	21' 4"	a.m. 6 35	1' 3"	p.m. 1 10	1' 7"	p.m. 5 30	3' 1"	a.m. 10 30	20' 1"
Sill at 6 feet above L.W.S.	21' 0"	a.m. 6 45	0' 7"	p.m. 1 48	2' 2"	p.m. 6 15	6' 7"	a.m. 11 15	20' 5"
Sill at 16·50 above L.W.S.	20' 11"	a.m. 8 15	2' 1"	p.m. 2 30	2' 5"	a.m. 7 45	2' 6"	a.m. 10 15	18' 10"

The coffer dam was carried up by horizontal planks, fastened to whole balk bearing piles, spaced at 6 feet centres ; the depth below L.W. springs 30 feet, and the height of finished embankment 26 feet over L.W. ; total height of dam, 56 feet ; width at bottom, about 120 feet.

The puddle was protected by means of lids and stuffing boxes filled with turf.

The vibration in the dam caused by a head of 5 or 6 feet of water on the sill was tremendous and very trying to the structure. Such a head ought, if possible, to be avoided by giving sufficient length of tumbling bay.

He would like to ask the author, with reference to his proposed method of dealing with Lord Headley's intake at Glenbeigh, would not Portland cement concrete laid between horizontal planks and lidded over be preferable to the expensive and slow method of building coursed masonry in hydraulic mortar ?

Poulnasherry Lagoon, near Kilrush, Co. Clare, is an instance of the failure to close an embankment by advancing from the ends.

The company built the bridges and laid the railway intended to be run from Kilrush to Kilkee, anticipating that the final closing would be a simple operation. They were not able to close, consequently the entire expenditure on the works was completely lost, and the embankment is now derelict.

Mr. Kernaghan, asked by the author why would he not prefer sheet piling to horizontal planking, said he referred specially to the case of closing a breach in an embankment where the range of tide is great, and the area flooded within the embankment of considerable extent.

From experience he found that although it was possible to drive sheet piling the work, under certain conditions, was useless on account of the greatly increased scour at the ends. Sheet piling may be used with advantage at the wings, but he approved of horizontal planking under the circumstances mentioned.

MR. RICHARD F. GRANTHAM, M. Inst. C.E., wrote :—

" As I have had upwards of twenty-five years' experience in constructing river and sea walls and embankments, in the erection of groynes, and in closing breaches in sea walls, it has given me much pleasure to read Mr. R. G. Allanson-Winn's paper on the Youghal Foreshore Protection Works. I regret that I am unable to attend the meeting on the 6th inst. to take part in the discussion on the paper.

" I think Mr. Allanson-Winn is to be congratulated on his

success in closing the serious breach west of Clay Castle, and in recovering by means of groynes the drift on the shore. In my experience there is no more difficult or anxious work for the engineer than in closing a gap made by the sea ; and that Mr. Allanson-Winn should have succeeded, apparently without a hitch, shows that the work must have been very skilfully done, aided perhaps to some extent by the comparatively low rise of tide at Youghal.

" At Brading, in the Isle of Wight, where 600 acres of low land were reclaimed from the sea by an embankment of sand, about ¾-mile in length, we experienced the greatest difficulty in closing the gap between the two ends of the embankment. Time after time the timber dam was destroyed, until at last we succeeded, but only for a time. As in Mr. Allanson-Winn's case, the embankment was not quite high enough, and the sea after some months again broke through. Eventually it was again shut out, the embankment raised, and the work has now stood the test of over 20 years. The embankment was made entirely of sand, with a chalk-pitched face.

" I see in Fig. VI. Mr. Allanson-Winn shows the level of the top of the embankment 5 feet above H.W.O.S.T., and he asks the question how many feet the top of an embankment should be taken above H.W.O.S.T.

" My experience is that where exposed to the open sea an embankment should not be less than 10 feet above H.W.O.S.T., and I have adopted this height for many years. Where the embankment is in an estuary of a river—the Thames for example—I have made them 3 feet above the highest known flood-tide, and in more sheltered creeks 1 foot 6 inches, and have found these heights sufficient. Mr. Allanson-Winn, by his reference to the breach in January last, appears to confirm the insufficiency of 5 feet in such a situation.

" There is no doubt that unless Mr. Allanson-Winn had

erected the groynes as shown on the sketch plan the embankment could not be maintained. The object of groynes is not as sea defences by themselves, but as a means of accumulating the sand and shingle, which when held in position are the natural defences of the coast.

"Lord Headley's embankment, as Mr. Allanson-Winn says, no doubt requires raising, and, being formed of the material described, would probably require frequent raising to maintain it up to its proper level. I have found embankments of some miles in length requiring raising 2 to 3 feet every 3 or 4 years, and they are composed of much more solid material than peat or bog stuff. Not only does the embankment itself settle, but the reclaimed land upon which it stands sinks too.

"It is difficult to understand without knowing the locality why Mr. Allanson-Winn should recommend masonry set in hydraulic cement for closing the breach in Lord Headley's embankment. The current through the breach runs, he says, with great force, so that without some protection it would seem that the cement would be washed out before it could set.

"The late Mr. Case, whose loss I much deplore, kindly showed me his groynes at Dymchurch, and I am able to testify to their success there, backed as they are by a stone-pitched slope ; but in discussion with him I ventured to doubt whether in that form they were applicable to all situations, and I am inclined to raise that question still.

"Mr. Allanson-Winn asks whether protective measures can be taken to stop the erosion on the coasts of Yorkshire, Norfolk, Suffolk, and Essex. I think without any doubt they can. But unless there be a large area of low-lying land behind the sea frontage, the cliff-land lost as agricultural land is not worth as a rule the cost of protecting.

"I do not quite follow Mr. Allanson-Winn in what he says about deep sea erosion. It appears to me on looking at his section (Fig. XII.) that the effect of this deep sea erosion is

-only relative. That is to say, I doubt whether the water at
·d′ on the section is deeper at its distance from the present
face of the cliff at B than the depth was at the same relative
·distance from the old face of the cliff at A. At all events,
Mr. Allanson-Winn shows the line c′ d′ to be parallel to the
·old sea bottom a b c. Or, in other words, say the depth at d′
is 30 feet, and the distance from a′ is 1,000 yards, is it to be
·supposed that at a distance of 1,000 yards from the old face
of the cliff at A the sea was less deep than it is now at d′
Perhaps, however, I have not grasped Mr. Allanson-Winn's
meaning on that point."

Mr. G. W. LAMPLUGH wrote :—

" I thank you for sending me a copy of Mr. Allanson-
Winn's paper, which I have read with great interest, and
regret that I cannot be present at the meeting to-morrow.

" From my personal knowledge of the Holderness Coast,
I can endorse Mr. Winn's statements as to the steady deepen-
ing of the sea floor which is in progress below low water mark,
and agree with him that this factor has been too frequently
overlooked in planning defence works. This deepening is
accelerated by the activity of boring molluscs (*Pholus*,
&c.) and other marine organisms which established them-
selves on the patches of clay when the sand and shingle is
swept aside, and crumble down the submarine surface by their
close-set perforations. Where there is a thick accumulation
of sand or shingle on the sea floor, however, this action is
arrested ; nor do I think that there can be any wearing down
of the surface by erosion where the sand and shingle is
sufficiently thick for the lower layers to remain quiescent
below wave and current influence. Therefore, if by groyning
or other means a mass of material could be arrested on any
part of the coast right down to low water mark, and a little
below it, so that there should be no friction and wearing
between the loose beach stuff and the " soft floor," the deepen-

ing might be so far arrested as to maintain the position of the low water mark for a long period. It is certainly of great importance in all defence work to keep the low water and high water marks as far apart as possible, or, in other words, to maintain as low a gradient as possible between these marks. A steep bank, readily set in motion, must be always difficult to maintain and liable to sudden alteration. It is, of course, only in the vicinity of towns or other land of exceptional value that the cost of protection of a wasting coast like that of Holderness by such methods as effective groyning or walling can be profitably borne."

Mr. L. M. FITZGERALD wrote :—

" I have read with much interest the pamphlet you so kindly sent me on the Youghal Foreshore by Mr. Allanson-Winn. There is no doubt the Case groynes have worked wonders in raising the shore where they have been put. There are groynes to the east of those for many years, which at times did more harm than good ; while the Case groynes are best from 9″ to 18″ over the level of the strand, and in short horizontal steps, offering little or no resistance to the sea. The old groynes are of heavy piling and sheeting, standing mostly four feet over the strand, and following the slope of same I have many times walked through the cuttings beneath these, and have seen the foundations of the sea walls they were put up to protect exposed to the very bottom. I have a long experience of the Youghal strand and sea-walls, and have seen almost all damage done from the back, sometimes through the drop of a heavy sea over a wall or bank, and at others I have seen the backing all sucked out through a small hole in the sea wall that could have been checked, if taken in time, at the cost of a couple of shillings, afterwards costing hundreds of pounds. I think if more attention was paid to the backing, and the back of all sea walls had a good layer of well rammed puddle, less damage would be done.

" There is 18 feet deep of solid peat beneath the sand on this shore, and at low springs I have picked up nuts from beneath the roots of old trees, and have seen the square cuttings in the turf as of a pre-historic turbary at the very place those Case groynes now are. Query : Are our shores sinking or the sea level rising ? In my recollection the sea has encroached over 500 feet on Clay Castle. In my younger days the old breakwaters could be seen from ' Moll Goggins,' corner (over the railway) ; now the breakwaters, or what is left of them, can be seen as if standing out on a promontory.

" My recollections of the cutting storms are contrary to the author's. The *on*-shore storms carried away the shingle, not moved it in, as he says."

The CHAIRMAN (Mr. Robert Cochrane, Vice-President) said the discussion had been very interesting, and important points had been raised, such as the question of high embankments and the description of packing used at the back. Of the speakers, Mr. Clark had given them his views on the geological aspect, which were valuable. Perhaps the author might be able to enlighten them on the question as to whether the land on the sea margin of the south coast of Ireland was lowering gradually. They heard it asserted from time to time that the land was sinking in the south and rising in the north.

The Chairman agreed with the author that it was not so much the sinking of the land as the erosive action of the sea. He had some experience of this at Ardmore Bay, only a few miles east of Youghal. The old road from the village of Ardmore to Dungarvan is now broken off at the bridge near the strand. This is the second road and bridge which have been destroyed by the rapid action of the sea, which within living memory has carried away the sites of two successive schoolhouses, and now threatens the eastern end of the village, where the third schoolhouse is built. The roads which were

washed away traversed comparatively high ground, 10 or 12 feet above high water, and between the high ground and the sea there was a strip of green pasture about 100 yards wide. This is shown on the ordnance map of 1842. This land, and the site of the county road, with the houses on both sides of it, as well as the diverted road subsequently made further inland, have all been destroyed by the erosive action of waves of the sea. Underneath a bank of shingle there is a bed of peat ; there are also traces of artificial work, including the site of a crannog, at a lower level than that of the present high water mark, and this shows that there was at one time a barrier in the shape of a raised beach, which kept out the sea from the peaty marsh which now forms the shallow bed of part of the Bay of Ardmore.

Further eastward, in the County of Wexford, is the Bay of Bannow, where there was within comparatively recent times a town of considerable size of that name which returned two members to the Irish Parliament ; there is now not a trace of a house. Survey maps are extant of a large tract of land here, the site of which is now under high water mark. The soil was of a sandy nature, easily acted on by the erosive action of the sea.

Continuing eastward in the same county, at Rosslare Point, a large quantity of land, with some important buildings, the property of the Crown, have disappeared within the last hundred years. There are many other examples on the south and south-west coast of sea erosion, but in the three cases mentioned he (the Chairman) had been engaged professionally, and had examined the sites with the original survey, which left no manner of doubt as to the actual disappearance of the lands.

This erosive process sufficiently accounts for the prevalent belief that the land is sinking. The true state of the case is that the level of the land is stationary, while the sea is

encroaching by the erosion of the loose soil where exposed to the action of the waves.

The idea that the land is rising in the north may be accounted for by the formation of the raised sea beaches from the Wicklow coast on the east around the northern coast. This formation is known to geologists as the 25 feet raised beach ; it extends to the west coast of Scotland. The largest tract of "raised beach" in Ireland is North Londonderry and near here, on the shore of Lough Foyle, some thousands of acres have been reclaimed from the sea by embankments, one of which was broken through by the storm and high tide of 26th February of this year.

It was interesting to know that the work accomplished by the author at the Youghal embankments had stood the test of the very severe storm of the date just mentioned, which showed that his work had been well and satisfactorily done.

MR. ALLANSON-WINN, in reply, said that Mr. Hewson need not have much fear of immediate loss at Greystones, as there was a great difference between that coast and the coast of Yorkshire. At Greystones, the cliff material was very much harder, and the sea was not making what might be called a "determined attack" or rapid advance on the land, as was the case on the Yorkshire coast and other places which might be mentioned.

He preferred to use sheet piling in places where the substratum was soft and an embankment breach had to be rapidly closed, though occasionally it might be better to plank up, between uprights, in horizontal layers. Where there was much depth a combination of the two plans might answer well.

On the morning after the big storm at Youghal, when a succession of south-easterly gales raged from the 12th of last January to the 16th, the entire surface of the shore was strewn with shingle and boulders of different sizes, ranging from 1 ℔. up to 50℔s. in weight—the largest now shown

weighing 32 ℔s. The fact that these heavy stones had all long attachments of *deep-sea seaweed* proved that they were torn from the bottom of the sea; and this again was sufficient to show that deep-sea erosion was going on, for, obviously, the space formerly occupied by these stones at the bottom of the sea was now occupied by salt water, or was it the actual time of movement. Deep-sea erosion during rough weather was thus clearly proved.

The information contained in Mr. Fitzgerald's letter was most interesting, coming as it did from a gentleman well acquainted with the Youghal district, and well able to judge of the changes which had recently taken place in the neighbourhood of Clay Castle.

With regard to the question of the land sinking in the south and rising in the north of Ireland, this was a matter which he had heard discussed for a great many years. It was held by some that the land was sinking round the Kerry coast, but he had never come across any definite or conclusive evidence to prove it. It often happened that the land rose towards the shore line, and then sloped inland till below high water mark—or, indeed, to mean sea level; then, when the encroaching sea cut through the steeper portion, the whole of the lower ground—possibly covered with roots of trees, &c.—was flooded by the sea at every tide. Hence the discovery of the roots of trees on the shore, *which had always been below high water mark,* led people to suppose that the shore itself had sunk.

With reference to the tide on occasions rising higher than the embankment, it was a matter of considerable difficulty to know what margin of safety should be allowed both as regards backwater embankments—as exemplified in the case of Lord Headley's embankment—and the Youghal embankment, which, aided by Case groynes, had to face the attacks of the open sea. For the latter 5 feet might be ample for 20

or 30 years, but would not answer for an exceptional tide aided by gales, such as had occurred at Youghal during the month of January last.

It would appear that there still existed some misunderstanding or misconception as to the exact meaning of deep-sea erosion and advance. If the fact of the present existence of 30 feet of water below the former sites of towns, villages, &c., which in the old days stood on dry land, is not clear enough evidence, let us consider the present position of the 5-fathom line. It will not be disputed that the present 5-fathom line is, roughly speaking, a mile out to sea on the Holderness coast of Yorkshire. In the old days, when towns, villages, &c., existed at that distance from the present shore, the then 5-fathom line was probably a mile or so further to the east—*i.e.*, about 2 miles from the present coast line. An examination of the charts shows a depth of 6, 7, and 8 fathoms at a distance of 2 miles from the shore; in other words, whilst the 5-fathom line has been advancing westward for one mile, the old 5-fathom line has deepened to the extent of 1, 2, or 3 fathoms. But, even if the old 5-fathom line did not show deeper soundings, the case would be as easily proved, for, whether the sea has deepened 2, 3, and 4 miles from the coast or not, the fact remains that we can now sound 5 fathoms below what was formerly dry ground. The idea that all this deep-sea erosion is caused by the surf action alone is hardly to be entertained, for we should have the almost impossible circumstance of surf action on the visible shore in range of, say, 16 feet, eroding the sea bottom at a depth of 30 feet, and at a distance of a mile or more

With reference to Mr. Grantham's remarks on the approach of deep water, I think the reason for the slight misunderstanding of my meaning is to be found in the rough typical section (Fig. XII.), in which the vertical scale is, of course, greatly exaggerated. The line *b' c' d'* should not be parallel to

the old sectional line *b c*, but *d* should be shown much closer to *c*.   My object is to show that deep-sea erosion is going on contemporaneously with, but independently of, surf erosion.

The 30 feet of sea water now found beneath the situations of ancient towns and dry cliffs cannot have been caused solely by breaker action on the cliffs.   The 5-fathom line of to-day must be less deep than the sea now is at the ancient 5-fathom line, which has deepened possibly to 5½ or 6 fathoms—the erosion becoming less and less as the gradient flattens out.

This we have proof of from sections taken out into the North Sea.   The 5-fathom line is now within one mile of the Holderness coast of Yorkshire, the 10-fathom line is about 6 or 7 miles from the coast, whilst the 25-fathom line is from 20 to 30 miles distant.

That erosion in deep water goes on independently of high water, or surface, erosion is sufficiently proved by the fact that, where protective devices have temporarily stayed the advance of the high-water mark, the low-water mark has continued to encroach inland until the shore has shortened and become steeper.

As a very general rule, in places where the erosion is steadily going on, the horizontal distance between high and low water marks remains practically the same, showing that the two sets of erosion are contemporaneous, or nearly so.   Then we have the very strong evidence afforded by those places where 30 feet of water is now found below the sites of ancient towns, and the even more strong direct evidence of the movement inshore of heavy material from the deep water in the offing.

I would summarise the causes of deep-sea erosion as follows :—

    1. The action of storms and currents in depths at present imperfectly ascertained—say, from 5 to 40 fathoms.

    2. The action of marine borers and worms casting up and honeycombing the sea's bottom.

3. The action of fresh-water springs bubbling up at various depths.*

The two last-named do not probably exert as much influence as the first, but they may be regarded as decidedly contributory, and it is hard to see how any of the three can be stopped by devices at a much higher level and in shallow water. My theory is only advanced with respect to those places where the material is soft for a considerable depth below low-water level, and where, also, the sea is making a steady and continuous advance on the land.

*Paper entitled "Sub-Oceanic Changes," by Professor John Milne, F.R.S., read at the Royal Geographical Society, June 18th, 1897, and reported in the Society's Journal for August and September, 1897, p. 17.
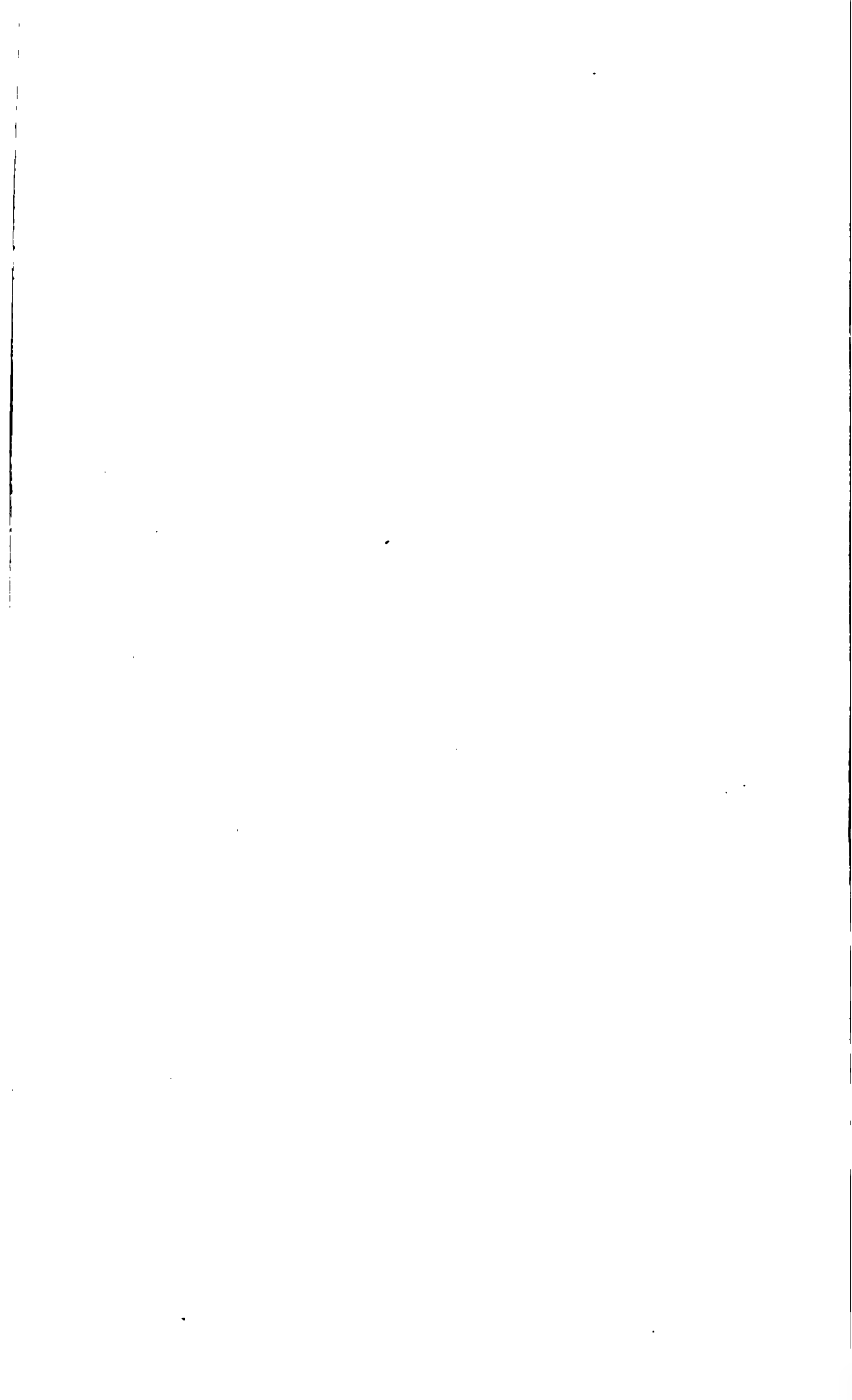
REPORT OF COUNCIL FOR 1902-1903.

THE numbers of Members, &c., at the close of this Session as contrasted with the previous one are :—

		Members	Associate Members	Associates
1902-3	-	150	54	54
1901-2	-	141	37	54

The Council in submitting their Report have pleasure in recording the continued prosperity of the Institution referred to in the Report for 1901-1902, both as regards increase of Members, Associate Members, and Associates, but would wish to see a similar increase to the Student Class, and consider that all the Members and Associate Members should lay the advantages afforded to Students by the Institution before their Pupils or others whom they know may be preparing to enter the Profession, and the Council trusts that the Institution will co-operate with them, should they consider that this desired increase to the Student Class justifies them in making arrangements for holding extra meetings during the Sessions, devoted entirely to the reading and discussion of papers brought forward by Students, Associates, or others interested in education in the different branches of the Engineering Profession.

The Council have the honour in recording the gracious reception afforded to them, and to the Members of the Institution, by His Excellency the Lord Lieutenant of Ireland, when receiving the Address* presented to His Excellency by the Institution, and also the great honour conferred by His Excellency in attending the Annual Dinner held in the Rooms of the Institution on 17th December,

* See pages 181-2.

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1902, as well as in his accepting, in compliance with the wish expressed by the President on behalf of the Institution, the proposal that he would honour the Institution of Civil Engineers of Ireland by allowing his name to be enrolled as an Honorary Member. Your Council gave effect to this at a Special Meeting of the Council on December 23rd, 1902, by electing unanimously His Excellency as an Honorary Member,

The Council wish especially to bring under the notice of the Members, Associate Members, Associates, and Students, that the Library has been largely increased with all the modern works treating on the different branches of the Profession, and they hope that any deficiencies will be brought under their notice. A Catalogue of the Library has been compiled by the Library Committee, consisting of Messrs. Dick, Mills, Pigot and Moore, to whom the Council feel sure the Institution will unite with them in tendering the thanks of the Institution, which they now do.

The Council have awarded the following prizes to the authors of papers read before the Institution at the Sessional Meetings :—A Mullins' Gold Medal to Mr. W. E. Lilly, Member, for his paper on "The Design of Plate Girders," read before the Institution, April 1st, 1903.

A Chaloner-Smith Premium to Mr. H. Norman Leask, Associate Member, for his paper on "The Destruction of Towns' Refuse, and some of the Principles involved in the Construction of Refuse Destructors," read before the Institution, March 4th, 1903.

A Mullins' Silver Medal to Mr. J. T. Trevor Dillon, Associate Member, for his paper entitled "Some Notes on Route Surveys with the Plane-table in Egypt," read before the Institution, March 18th, 1903.

A Mullins' Silver Medal to Mr. R. G. Allanson-Winn for his paper on "Foreshore Protection at Youghal; and Deep

Sea Erosion on the East Coast of England," read before the Institution, May 6th, 1903.

It being contrary to custom to award Medals or Premiums to Members of Council, the special thanks of the Council were tendered to Mr. Mark Ruddle, Member of Council, for his paper on "Electrical Transmission and Transformation of Energy."

The Council record with regret the loss to the Institution by death of the following:—Mr. Samuel W. Nugent, Mr. C. H. Moberly, Mr. Wm. Banks, Members; and Mr. John Newbigging, Mr. Lionel N. Galbraith, Associate Members.

The following papers were read during the Session, 1902-3:—

December 3rd, 1902—Address of the President, Mr. John H. Ryan. January 7th, 1903—" Electrical Transmission and Transformation of Energy," by Mr. Mark Ruddle, Member of Council. March 4th, 1903—" The Destruction of Towns' Refuse, and some of the Principles involved in the Construction of Refuse Destructors," by Mr. H. Norman Leask, Associate Member. March 18th, 1903—" Some Notes on Route Surveys with the Plane-table in Egypt," by Mr. J. T. Trevor Dillon, Associate Member. April 1st, 1903— " The Design of Plate Girders," by Mr. W. E. Lilly, Member. May 6th, 1903—" Foreshore Protection at Youghal; and Deep Sea Erosion on the East Coast of England," by Mr. R. G. Allanson-Winn, Member.

⚙bituary Notice

LIONEL NORMAN GALBRAITH

LIONEL NORMAN GALBRAITH, who died at Obuassi, Ashanti,
West Africa, on the 4th June, 1903, from exhaustion, following
an attack of hæmoglobinuric (Blackwater) fever, was the
youngest son of Mr. A. W. Galbraith, C.E., of Southampton,
being born on the 21st May, 1880. He was educated at
Winchester, subsequently attending the London Polytechnic,
Regent-street, W. He was then articled to his father, and
during that period was engaged upon several works in the
South of England, connected with the latter's private practice.

In November, 1900, he was appointed a junior Assistant-
Engineer under the Crown Agents for the Colonies upon the
Gold Coast Government Railways, Messrs. Shelford & Sons,
of Westminster, being the Consulting Engineers, and was
employed upon the Sekondi Tarkwa Section. In December,
1901, he was specially attached to the Lagos Nigeria Railway
Extension Survey Party under Mr. W. Gee, M. Inst. C. E.
This expedition proceeded up the River Niger, as far as Jebba,
to select and survey a possible site for a bridge, and, that
found, to run a reconaissance survey from thence to Horin, in
Northern Nigeria, to connect with the survey of the season
before. Owing to the very satisfactory nature of his services
he was promoted to the higher grade of Assistant Engineer,
and at the time of his death was engaged in that capacity on
the Kumasi extension of the Gold Coast Railways.

He was elected an Associate of the Society of Engineers on
the 3rd November, 1902, and was admitted to the Associate
Membership of the Institution on the 4th February, 1903.
He was but 23 years of age, being a young Engineer of
exceptional promise, and his frank, fearless, loyal, genial,
generous and affectionate nature endeared him to all with
whom he was brought in contact.—

Quam di diligunt adolescens moritur.

ADDRESS

TO

HIS EXCELLENCY THE LORD LIEUTENANT.

To His Excellency The Earl of Dudley, Lord Lieu-
tenant-General and General Governor of Ireland.

May it Please Your Excellency,

We, the President, Council and Members of the
Institution of Civil Engineers of Ireland, beg to offer our
heartfelt congratulations to Your Excellency on your appoint-
ment to the high office of Lord Lieutenant of Ireland.

We take this opportunity of expressing the sentiments of
devotion and loyalty which our Institution has always held
towards the Sovereign, and feel that in you his Majesty the
King has a worthy representative. We feel confident that
your advent will mark the beginning of an era of increased
prosperity to Ireland, and that Your Excellency and the
Countess of Dudley may long be with us.

Her late Majesty Queen Victoria, at an early period of her
long and happy reign, conferred on our Institution her Royal
Charter, which we still hold and look upon with pride.

Members of our Institution all over the world have con-
tributed largely to the building up of the Empire ; and in
Ireland we also look with pardonable pride upon the part our
members have taken in the many great works of public
utility which have so largely aided the development of the
country, and many of which owe their being to the fostering
care and enlightened policy of the Government.

We have observed with pleasure that within the short
time at your disposal Your Excellency and the Countess of

Dudley have evinced a great interest in the industries of our country, and we feel satisfied that your visit to the different parts of Ireland will result in enabling Your Excellency to form a favourable opinion of the opportunities available for materially advancing its prosperity.

Signed on behalf of the Institution of Civil Engineers of Ireland.

JOHN HENRY RYAN, *President.*

ROBERT COCHRANE,
WILLIAM ROSS, } *Vice Presidents.*

WILLIAM ANDERSON.	MARK RUDDLE.
FRED J. DICK.	SAMUEL J. SHANNON.
JOSEPH H. MOORE.	PROSSER A. H. SHAW.
GEORGE M. ROSS.	RICHARD O'BRIEN SMYTH.

MARMADUKE BACKHOUSE, *Hon. Secretary.*

AUDITORS' REPORT.

DEAR SIRS,

We have completed the audit of your Books for the
Year ended 31st December, 1902, and send you herewith
Revenue Account and Balance Sheet duly certified. We have
verified the Entrance Fees and Subscriptions by an
examination of the counterfoils of the receipts issued, and
we have seen that all the Rents receivable and dividends on
Investments have been duly accounted for.

The balance on the Revenue Account shows an excess of
expenditure over income of £95, compared with £151 a year
ago.

The Income from Subscriptions and Entrance Fees shows
an increase of slightly over £100.

The Expenditure amounts to £658 compared with £616 a
year ago, an increase of £42, the result being a reduction in the
excessive expenditure as mentioned above.

BALANCE SHEET.

The Liabilities were obtained from the Secretary, and we
understand from him that all liabilities have been included.
We saw that a considerable portion of these Liabilities have
been paid since the books were closed. The Subscriptions

in arrear amount to £51 19s., and compare very favourably with the amount outstanding a year ago—namely, £82.

During the year only £2 2s. was written off as bad, and we are given to understand all of this £51 19s. will be recovered.

We obtained certificates from the Bank of Ireland that the stocks represented by Consols and India $3\frac{1}{2}$ per cent. stock were standing in the names of the Trustees of the Institution.

The Cash in Bank we verified by an examination of the Bank Pass Book.

We, are,
Yours faithfully,
CRAIG, GARDNER & CO.

A N D.

Dr.			Cr.		
	s.	d.	£	s.	d.
To Pri	.		46	4	0
A	13	6			
	8	0			
I	1	6			
	19	6			
„ Re					
A	2	0			
	18	6			
I	0	6			
	6	0			
„ Ra			309	14	6
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A	10	0			
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I	10	0	167	0	0
	15	5			
	8	10			
„ Ex					
	4	3			
„ Sal	9	2	37	15	1
A					
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„ Illu					
Total, £			658	6	9
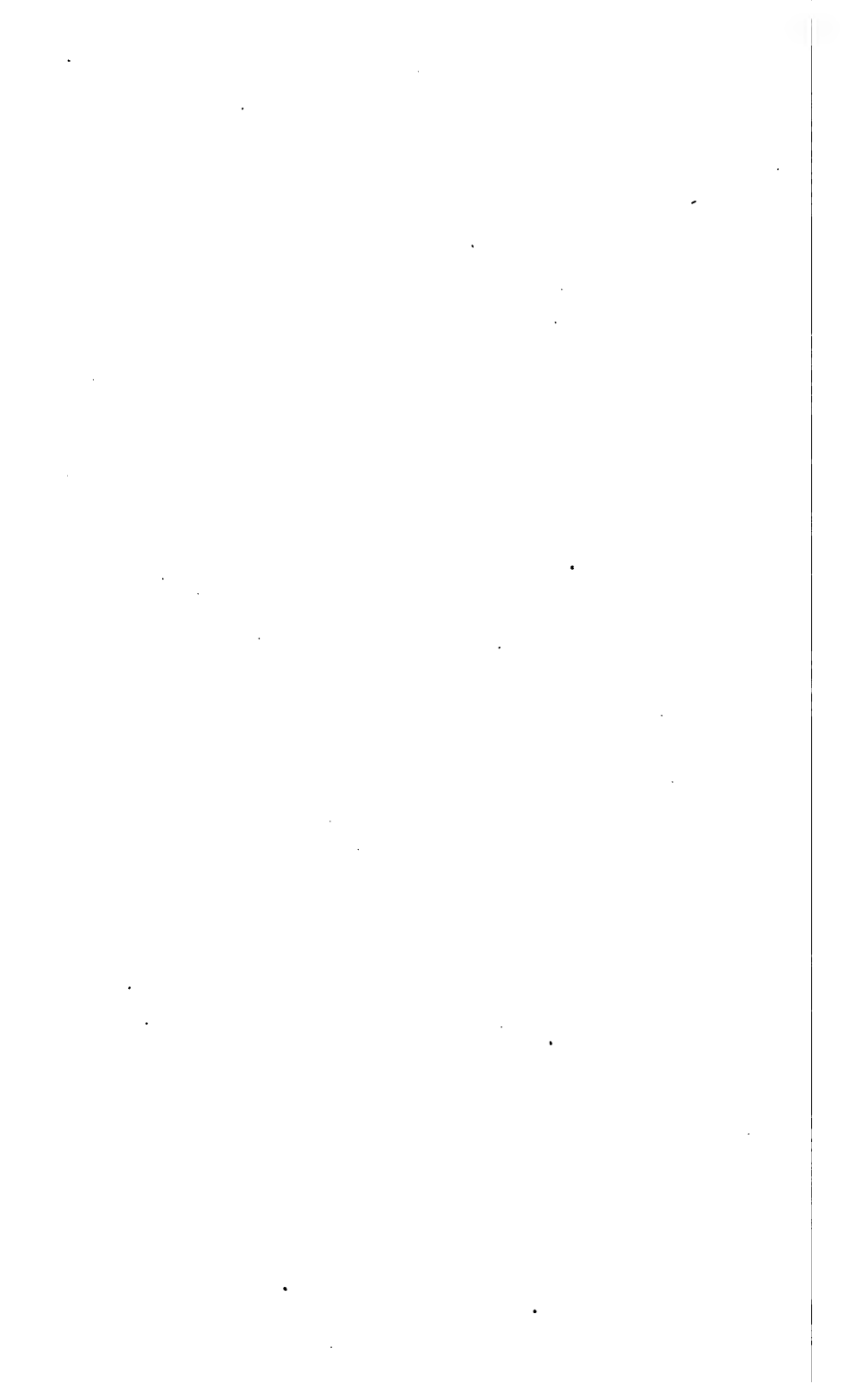
THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

BALANCE SHEET made up to 31st December, 1902.

ASSETS.	£ s. d.	£ s. d.
To Subscriptions in Arrear . . .	61 18 6	
Less paid in advance for 1903 . .	9 19 6	
	51 19 0	
,, The Mullins' Bequest, £1,172 8s. 3d., 2½ per cent. Consols	1,172 8 3	
,, Smith Testimonial Fund, £97 14s. 7d., India 3½ per cent. Stock	97 14 7	
,, India 3 per cent. Stock, £185 4s. 6d. .	149 15 5	
,, Rents receivable, due . . .	132 10 0	
,, Dividends on Investments due . .	9 8 10	
,, Rates and Insurance paid in advance .	9 10 0	
,, Cash in Bank	159 9 3	
,, Premises 35 Dawson-street, Dublin, held under lease for 200 years from 1892, subject to annual rent of £105 and rates . .	—	
,, Library	—	
,, Furniture and fittings . .	—	
Total, £	1,782 15 2	

LIABILITIES.	£ s. d.	£ s. d.
By Sundry Creditors—		
Accrued Rent . . .	22 15 0	
Repairs and Taxes . .	13 6 3	
Printing and Stationery .	40 15 6	
Annual Dinner . .	50 0 0	
Law Expenses . .	13 11 0	
Books for Library .	31 5 0	
Furnishing Reading Room .	1 1 0	
Fuel and Light . .	2 17 7	
		175 11 4
,, Surplus to the credit of the Institution at 31st December, 1901, exclusive of the value of Premises, Library, Furniture, and Fittings .	1,703 1 6	
Less Debit Balance of Revenue Account for 1902 .	95 17 8	
		1,607 3 10
Total, £		1,782 15 2

Publications received in exchange for Institution Transactions.

Engineering.	The Timber Trades Journal.
The Engineer.	The Indian and Eastern Engineer.
The Builder.	Indian Engineering.
The Contract Journak	Caissier's Magazine.
The Surveyor.	Engineering Record (New York).
Traction and Transmission.	Railway and Tramway World.

Electrical Review.

The Volumes of Transactions are exchanged with the following
Institutions, &c. :—

American Academy of Arts and Sciences.	Boston.
American Society of Civil Engineers.	New York.
American Society of Mechanical Engineers.	New York.
Canadian Society of Civil Engineers.	Montreal.
Engineers' Club of Philadelphia.	Philadelphia.
Franklin Institute.	Philadelphia
Institution of Civil Engineers.	London.
Institution of Mechanical Engineers.	London.
Institution of Engineers and Shipbuilders in Scotland.	Glasgow.
Junior Institution of Engineers.	London.
Liverpool Engineering Society.	Liverpool.
Midland Institute of Mining, Civil, and Mechanical Engineers.	Barnsley
North of England Institute of Mining and Mechanical Engineers.	Newcastle
Nova Scotian Institute of Science.	Halifax, N. S.
Royal Engineer Institute.	Chatham.
Royal Institute of British Architects.	London.
Royal Scottish Society of Arts.	Edinburgh.
Royal Society of Antiquaries of Ireland.	Dublin.
Smithsonian Institution.	Washington.
Sociedad Cientifica Argentina.	Buenos Ayres.
Society of Arts.	London
Society of Engineers.	London.
Surveyors' Institution.	London.
West of Scotland Iron and Steel Institute.	Glasgow.
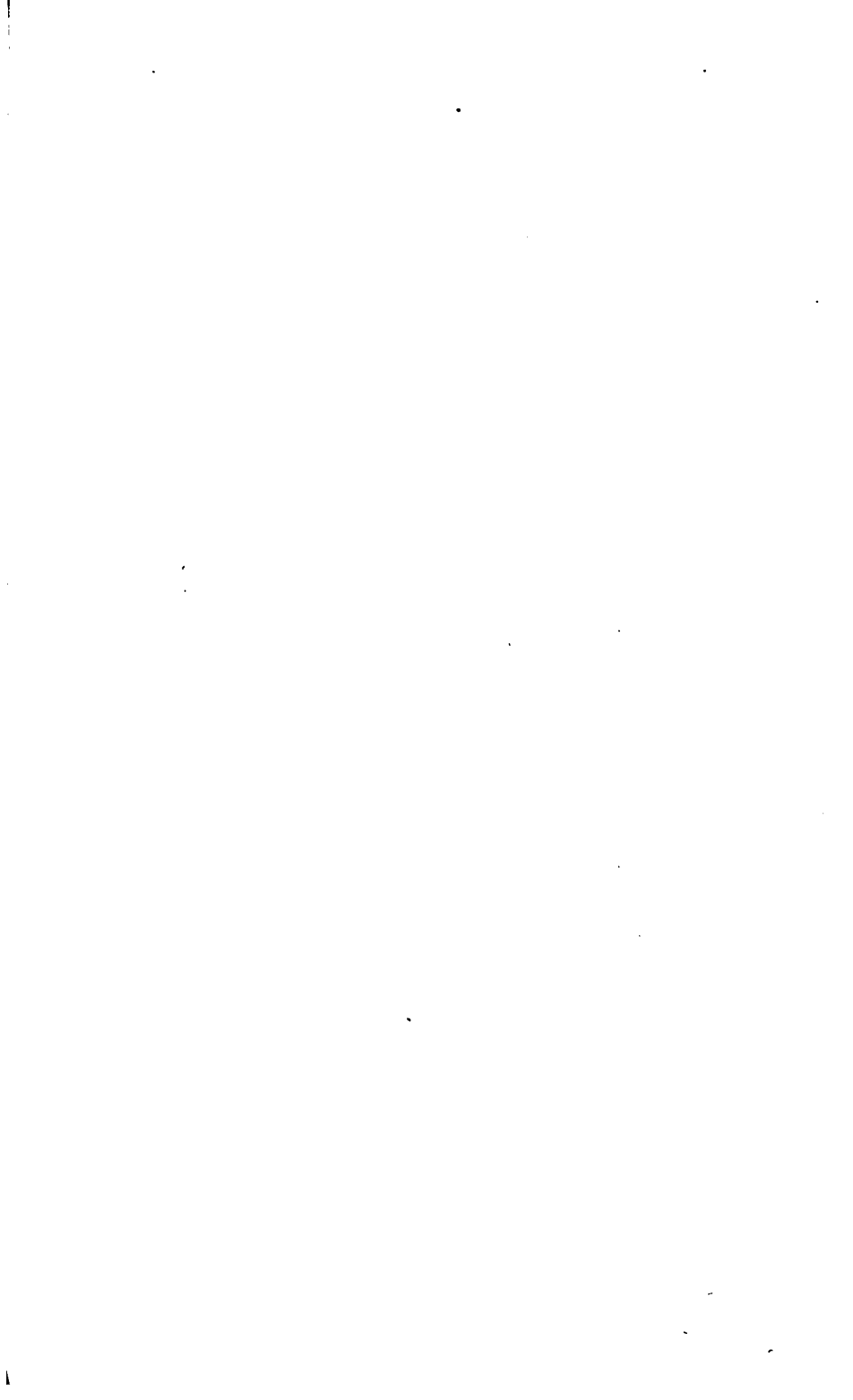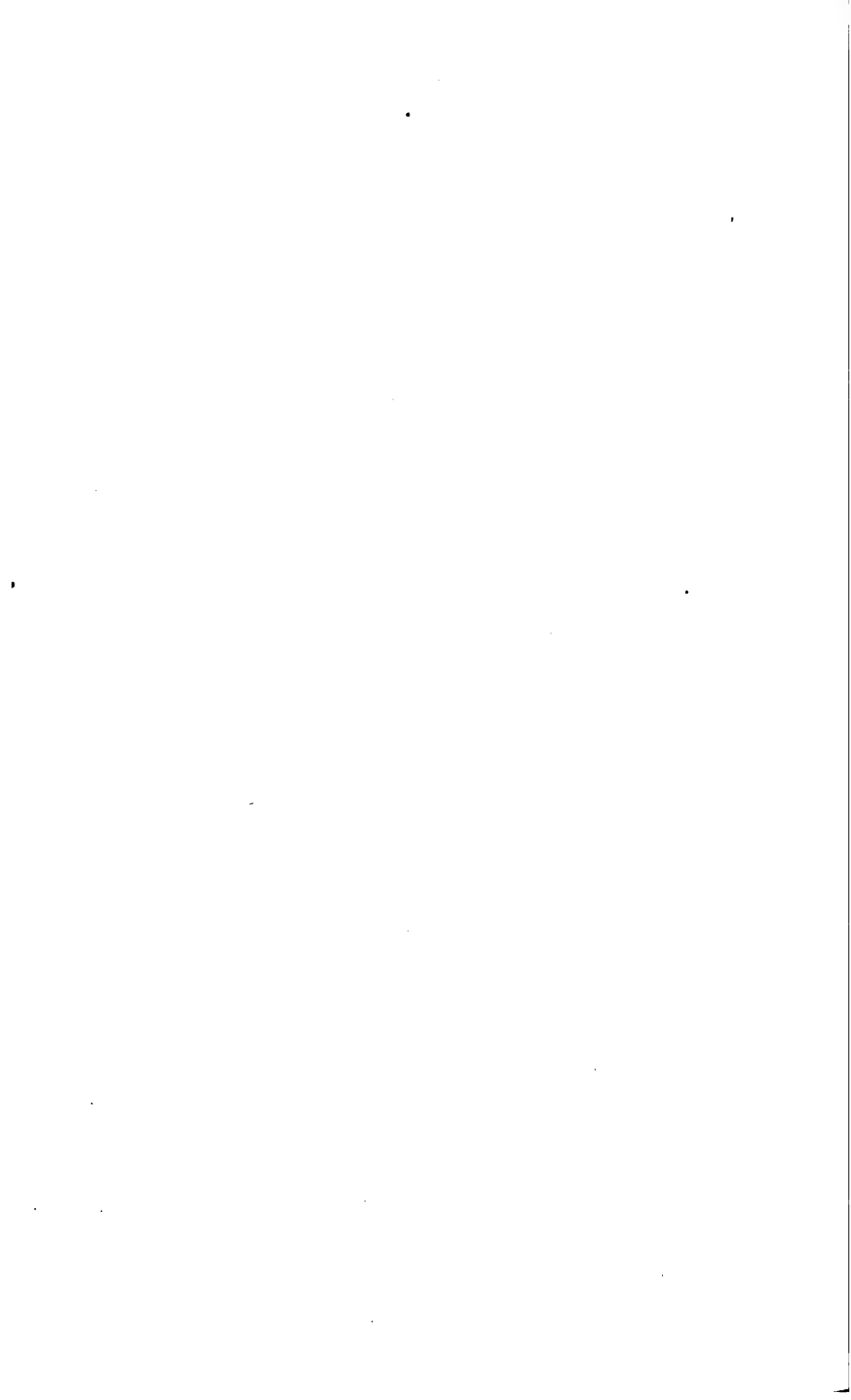
LIST OF MEMBERS.

INSTITUTION

OF

CIVIL ENGINEERS OF IRELAND

ESTABLISHED 1835 (INCORPORATED BY ROYAL CHARTER, 1877),

35 DAWSON-STREET, DUBLIN.

1903.

COUNCIL.

President:
JOHN HENRY RYAN.

Vice-Presidents:

ROBERT COCHRANE,   WILLIAM ROSS, (*Hon. Treas.*)

Other Members:

WM. ANDERSON,	MARK RUDDLE,
FRED. J. DICK,	PROSSER A. H. SHAW,
WM. PURCELL O'NEILL,	RICHD. O'BRIEN SMYTH,
GEORGE M. ROSS,	BERKELEY D. WISE.

Past Presidents:

BINDON B. STONEY,	JOHN P. GRIFFITH,
CHARLES P. COTTON,	SPENCER HARTY,
ALEX. M'DONNELL,	THOMAS F. PIGOT,
WILLIAM H. MILLS,	JAMES DILLON,
JOHN A. F. ASPINALL,	EDWARD GLOVER.

Honorary Secretary:
MARMADUKE BACKHOUSE.

Bankers:
ROYAL BANK.

Members are requested to inform the Honorary Secretary if any correction be necessary.

HONORARY MEMBERS.

(Hon. M.Inst.C.E.I.)

ELECTED

1902 Rt. Hon. William Humble, Earl of Dudley, Lord Lieutenant-General and General Governor of Ireland . . . Vice Regal Lodge, Dublin.

1868 M ⎱ Grubb, Sir Howard, Rockdale, Orwell-road, Rath-
1882 H.M. ⎰ F.R.S., F.R.A.S., &c. gar, Dublin.

1897 Cameron, Sir Chas. A., C.B., M.D., F.R.C.S.I. . . . 51 Pembroke-road, Dublin.

1901 Thrift, Professor W. E., F.T.C.D. Trinity College, Dublin.

MEMBERS.

(M.Inst.C.E.I.)

1901 Allanson-Winn, Rowland Geo. A., 22 South Frederick-st., Dublin, B.A., Cantab. and Glenbeigh, Killarney.

1892 Alexander, *Professor* Thomas, M.A.I. . . . . 39 Trinity College, Dublin.

1898 Allen, Henry . . . . Rehoboth House, South Circular-road, Dublin.

1869 F.L.A.⎱ Apjohn, James Henry 17 Victoria-street, West-
1875 F.L.M.⎰ M.A., M.Inst. C.E., minster, London, S.W.
(L.M.)

1880 Armstrong, George Allman . Timoleague and Courtmacsherry Light Ry., Bandon, Co. Cork.

1877 Aspinall, John Audley Frederick, Gledhill, Mossley Hill Drive, M. Inst. C.E. *(L.M., Past* Sefton Park, Liverpool. *President)*

1903 Atock, Thomas, B.A. . . 25 Cabra-road, Dublin.

1880 Backhouse, Marmaduke, M.A.I. 9 Harcourt-terrace, Dublin. *(Honorary Secretary)*

1902 Bain, Andrew (Major, R.E.) Commissioner of Civil Police, *(L.M.)* Northern Nigeria, West Africa.

ELECTED

1896 Barnard, Albert William . . Coolyhane House, Macroom, Co. Cork.

1896 Barnes, Robert Stephenson . Tatestown, Navan, Co. Meath.

1876 A⎱ Barnes, John Frederick Maritzburg, Natal, South
1879 M⎰ Evelyn, M.Inst. C.E. Africa.
(*F.L.M.*)

1874 A⎱
1880 M⎰ Barrington, Edward . . 3514 N. St., N.W., Wash., D.C., U.S.A.

1865 Beatty, John . . . . India.

1892 Bergin, Francis, B.E. . . Beech Grove, Kildare.

1899 Bergin, John Philip . . . Dublin County Council Offices, 11 Rutland-square, Dublin.

1890 Berry, Joseph . . . Town Hall, Kingstown, Co. Dublin.

1883 Birch, Edward Robert, . . Birch Grove, Roscrea.
Assoc. M. Inst. C.E.

1900 Brett, Henry Charles . . 19 Wellington road, Dublin.

1874 Brett, John H. (*L.M.*) . . Co. Surveyor, Antrim; Belfast.

1895 Buckley, Michl. J. . . . 26 Bessboro'-terrace, North Circular-road, Dublin.

1876 A⎱ Chappell, Henry . . The Grove, Newtownards, Co.
1883 M⎰ Down.

1895 Clarke, Eugene O'Neill . . County Surveyor, Leitrim ; Carrick-on-Shannon.

1865 Clark, George R. . . .

1870 A⎱ Cochrane, Robert, M.R.I.A., Board of Works, Dublin, and
1882 M⎰ F.S.A., F.R.I.B.A. (*Vice-* 17 Highfield-road, Rathgar.
President)

1888 Coey, Robert . . . . St. John's, Island Bridge, Dublin.

1890 Coffee, Francis R. . . . 2 Eaton-terrace, Tramore

4

ELECTED

1902 Collen, Wm., M. Inst. C.E. . County Surveyor, Dublin, 70
Upper Leeson-street, Dublin.

1886 Comber, Patrick Forstall . . 19 Lower Leeson-street,
M. Inst. C.E., F.S.I. Dublin.

1865 Cooke, Theodore, M.A., M.A.I., Portswood, Kew Gardens,
LL.D., C.I.E., F.G.S., F.L.S. Surrey.
(*F..L.M.*)

1861 Cotton, Charles Philip, M.Inst. Ryecroft, Bray, Co. Wicklow.
C.E. (*Past President*)

1900 Cowan, Peter Chalmers, M. Inst. Local Government Board,
C.E. Dublin.

1860 Crawford, Robt., M.E., M. Inst. Stonewold, Ballyshannon, Co.
C.E. Donegal.

1883 Creery, Leslie, B.A.I. . . Fortal, Killiney, Co. Dublin.

1892 Cusack, Henry Edward . . M. G. W. Ry. Works, Broad-
stone, Dublin.

1902 Davis, Charles Henry (*F.L.M.*) 25 Broad street, New York.

1884 A⎫ De Burgh, Ernest Macartney Union Bank of Australia,
1899 M⎭ Sydney, N.S.W.

1900 Dick, Fred. J., M. Inst. C.E. Board of Works, Dublin.
(*Member of Council*)

1863 Dillon, James, M. Inst. C.E., 36 Dawson-street, and Strat-
(*Past President*) ford House, Glenageary,
Co. Dublin.

1898 Dixon, E.K., M. Inst. C.E. . County Surveyor, South Mayo;
Castlebar.

1862 Dodd, George (*F.L.M.*)

1888 Doyle, Patrick (*F.L.M.*), . 19 Lall Bazar, Calcutta.
M.R.I.A., F.R.S.

1878 Duffin, William Edmund County Surveyor, Waterford;
L'Estrange Larkfield, Waterford.

1898 Fallon, Bernard N. . . . Netterville Lodge, Toomard,
Ballinasloe.

1873 A⎫ Ferguson, William, B.E., Harbour Board, Wellington,
1899 M⎭ M.A. M. Inst. C.E. New Zealand.

1900 Fortescue, Matthew, . . 57 Grosvenor-road, Rathgar.

ELECTED.

1894 Fletcher, Francis Dudley . . Shannon Office, Board of Works, Limerick.

1903 Gallagher, Stephen Gerald . Corballis Castle, Rathdrum, Co. Wicklow.

1875 Geoghegan, Samuel . . The Grove, Killiney, County Dublin.

1888 A }
1893 M } Gilcriest, William Fawcette   Wine-street, Sligo.

1877 Glover, Edward, M.A., B.E., M. Inst. C.E., F.R.I.B.A. (*Past President*)   County Surveyor, Kildare; Courthouse, Naas.

1887 A }
1892 M } Going, Shirley Russell (*L.M.*)   17 Nassau-street, Dublin, and 35 Sandycove-road, Kingstown, Co. Dublin.

1895 Gray, George David . . 36 Edenvale-road, Ranelagh, Co. Dublin.

1887 Greenhill, William . . . Great Northern Railway, · Dundalk.

1871 Griffith, John Purser, M.Inst.C.E. (*Past President*)   Greenane, Temple-rd., Rathmines, and Port and Docks Office, East-wall, Dublin.

1886 A }
1899 A.M. } Hade, Wm. Patrick . Dublin-street, Carlow.
1902 M }

1898 Hargrave, Joshua Harrison, B.A., B.E.   . Great Northern Railway, Amiens-street, Dublin.

1898 A }
1902 M } Harriss, George Marshall .   Barrow House, Carlow.

1875 Harty, Spencer . . . (*Past President*)   5 Trevelyan-terrace, Rathgar, and Engineer's Office, City Hall, Dublin.

1896 Haycroft, James Isaac (*F.L.M.*)   Fontenoy, Ocean-st.,Woollahra, Sydney, New Sth. Wales.

1872 Heenan, Robert Henry, M. Inst. C.E.   Port Elizabeth, Cape Colony.

ELECTED

1887 Henderson, Ernest . . . Canadian Pacific Railway, Smithfalls, Ontario, Canada.

1902 Hickson, George A.E., B.A.I. . 25 Denny-street, Tralee.

1895 Hill, William Henry, junr. . Audley House, Cork.

1903 Holmes, Geo. C. V. . . Chairman, Board of Works, Dublin, Dornden, Booters-town, Co. Dublin.

1901 Hope, John Basil . . . M. G. W. Ry. (Loco. Engineers' Dept.), Broadstone, Dublin.

1897 Hurtzig, Arthur Cameron, M.Inst. 2 Queen Square Place, West-C.E. minster, London, S.W.

1882 Ivatt, Henry Alfred, M. Inst. C.E. Gt. Northern Ry., Doncaster. (*Past Vice-President*)

1893 Johnston, George Leopold . Armagh Waterworks, Armagh

1901 Jolly, James . . . . School-lane, Didsbury, Man-chester.

1877 Joyce, Arthur Edward, . . County Surveyor, Westmeath; Ballinagore, Co. Westmeath.

1896 Keating, Wm. Johnson, B.E. . 28 York-road, Rathmines, Dublin.

1887 Kernaghan, William . . . 11 Rutland-square, Dublin.

1902 Kirwan, Robert Joseph, B.A., Gardenfield, Tuam. B.E.

1901 Latham, Frank . . . Municipal Buildings, Penzance.

1883 Latimer, John . . . . 11 Denny street, Tralee.

1898 Leahy, James D. . . . Newcastle West, Co. Limerick.

1889 Leask, Robert H. . . . 37 College-green, Dublin.

1901 Lilly, Walter Elsworthy . . 39 Trinity College, Dublin.

1856 Lyons, M. E. (*F.L.M.*) . .

1884 Manning, William . . Cookstown, Kells, Co. Meath.

1896 Martin, Frank V. (*I..M.*) . 82 North Wall, Dublin.

1898 Maunsell, Richard Edward . Mount Vernon, Inchicore,
Lloyd   Dublin.

1884 Maxwell, John Francis, M.A. . Lisna Arran, Rostrevor.

1903 MacDermott, Alfred Tudor . 51 Upper Mount-st., Dublin.

1860 M'Donnell, Alexander, M.Inst. Rydens, Hersham-road,
C.E. (*Past President*)   Walton-on-Thames.

1880 M'Donald, Donald . . . Curran, Larne Harbour, Co.
     Antrim.

1882 A ⎱ M'Mullen, James F. . . 30 South Mall, Cork.
1892 M ⎰

1882 Metge, Peter Ponsonby . . Creggan, Athlone.

1877 Mills, William Hemmingway, Nurney, Glenageary, and
M.Inst.C.E. (*Past President*) . Great Northern Railway,
     Dublin.

1869 A ⎱ Moore, Joseph Henry, M.A.I., County Surveyor, Meath ; 63
1874 M ⎰ T.C.D. . . . . Eccles-street, Dublin.

1900 Moore, William P. . . . 11 Herbert-road, Sandymount,
     and Port and Docks Office,
     East Wall, Dublin.

1879 A ⎱ Morony, Henry Vereker Lloyd, Harbour Commissioners'
1882 M ⎰ B.E., Assoc. M. Inst. C.E.   Office, Limerick.

1866 Morris, Thomas B., M. Inst. Messrs. King, King & Co.,
C.E.   Bombay.

1888 Morris, William Henry . . Belfast and Co. Down Ry.,
     Belfast.

1881 Moynan, John Ousley, M.A. . Co. Surveyor, North Tipperary,
     Nenagh.

1888 Moynan, Joseph, B.E., Assoc. Dundas Shire, Hamilton, Vic-
M. Inst. C.E.   toria, Australia.

1883 Mulvany, Christopher, M.A., . County Surveyor, Roscommon;
B.E., M. Inst. C.E.   Athlone.

1882 Myles, Thomas Joseph, B.A., . Engineer's House, M.G.W.
M. Inst. C.E. . Ry., Athlone.

1901 Montgomery, Henry Bevan . 5 Elgin-road, Dublin.
Slator, L.C.E., T.C.D.

ELECTED		
1896	O'Neill, William Purcell (*Member of Council*)	Highfield, N.C. Road, Dublin, and Engineer's Office, M.G.W. Railway.
1887 A⎫ 1899 M⎭	Ormsby, Charles Croasdaile	District Engineer's Office, M. G. W. Ry., Galway
1869 A⎫ 1876 M⎭	Ormsby, Robert Daly .	St. Kevin's, Dalkey.
1892 A⎫ 1898 M⎭	O'Sullivan, John G., Assoc. M. Inst. C.E.	2 Charleville-terrace, N.C.R., Dublin.
1901 A.M. ⎫ 1903 M. ⎭	O'Sullivan, Patrick F. .	Tolka View, Richmond-road, Fairview, Dublin.
1903	Ormsby, Michael Thos. Morley	95 Abbeville-road, Clapham, London, S.W.

1888	Parry, William Kaye, M.A., B.E., M.Inst. C.E., F.R.I.B.A.	63 Dawson-street, Dublin, and 6 Charlemont-terrace, Kingstown.
1898	Parshall, Horace F. . .	Salisbury House, London Wall, London, E.C.
1891 A⎫ 1891 M⎭	Payne, Sinclair William .	Upton House, Cork.
1895	Perrott, William George, B.A., B.E., Assoc. M.Inst.C.E.	Gracefield House, Blackrock, Co. Dublin.
1874	Pigot, Thomas F. (*Past President*)	14 Fitzwilliam-place, Dublin.
1903	Pilkington, Thomas Henry .	Glenard, Clare Castle.
1897	Porter, Samuel . . .	27 Beresford-road, Oxton, Cheshire.
1897	Price, Alfred Dickinson, M.A. Ing., M. Inst. C.E.	3 Fortfield-villas, Palmerston-park, and Local Government Board, Dublin.
1896	Price, James, M. Inst. C.E. .	Engineer, Harbour Commissioners, Cork.
1865	Price, W. H., M. Inst. C.E. .	Southsea.
1883 A.⎫ 1901 M.⎭	Purcell, Marmaduke . .	78 Upper Leeson-st., Dublin.

1900 A.M.⎫ 1903 M.⎭	Quigley, John . .	Holmdale, Seafield-road, Clontarf, Dublin.

9

1874 A} Ross, George Murray, M.A.,   63 Dawson-street, Dublin.
1893 M}   B.E. (*Member of Council*)

1884 Ross, William, B.A.I., T.C.D.   66 North Wall, Dublin, and
(*Vice-President and Hon. Treas.*)   Summerfield, Dalkey.

1893 Rowe, James Thomas   .   .   25 St. Andrew's-terrace, North Circular-road, Dublin.

1896 Ruddle, Mark, M.I.E.E. (*Member of Council*)   7 Lansdowne-terrace, Shelbourne-road, Dublin.

1902 Ryan, Hardinge Stanley, B.A.I.   29 Upper Pembroke-street, Dublin.

1896 Ryan, John Henry, M.A., M.Inst. C.E. (*President*).   22 Nassau-street, Dublin.

1882 A} Shannon, Samuel James, B.E.   Claremont, Meath-road, Bray.
1887 M}

1881 Shaw, Prosser Austin Haynes, L.C.E., T.C.D. (*Member of Council*)   21 Clarinda-park, Kingstown, and St. James' Gate Brewery, Dublin.

1896 Smith, John Chaloner   .   .   Engineer's Office, Board of Works, Dublin.

1861 Smyth, John, M.A., F.C.S.   .   Milltown, near Banbridge.

1881 A } Smyth, Richard O'Brien   .   2 Kenilworth-square, Rathgar,
1894 M } (*Member of Council*)   and Local Government Board, Dublin.

1898 Spunner, Henry Francis   .   18 South Mall, Cork.

1882 Stewart, Abraham M'Causland, B.E.   5 Castle-street, Derry.

1902 Stirling, J. A. Maxwell (*F.L.M.*)   South Indian Peninsular Railway, Camp Warora, Central Provinces, India

1857 Stoney, Bindon Blood, F.R.S., LL.D., M.R.I.A., M.Inst.C.E. (*L.M., Past President*)   14 Elgin-road, Dublin.

1868 Stoney, Edward Waller, M.E., M. Inst. C.E. (*F.L.M.*)   Chief Engineer, Madras Railway, Royapuram, Madras.

1873 Stoney, Robert Vesey (*L.M.*)   .   Rosturk Castle, Co. Mayo.

1872 Stoney, Thomas Butler (*F.L.M.*)   Oakfield, Raphoe, Co. Donegal.

1880 Spence, William   .   .   .   107 Cork-street, Dublin.

1891 Sutter, Charles H. N.   .   .   42 Dame-street, Dublin.

ELECTED

1844 Tate, Alexander (*L.M.*) . . Rantalard, Belfast.

1882 Thomson, Frank William, B.E.

1901 Towle, John William . . Moscow Mansions, Cromwell-road, South Kensington, London, S.W.

1860 Tuthill, Robert Reeves . . 9 Mount Avenue, Ealing, London, W.

1893 Vereker, Henry Robert, F.S.I. . Shevdilla, Westport, Co. Mayo.

1865 Waller, George Arthur, M.A. (*L.M.*) Cangort Lodge, Hobart, Tasmania.

1862 Walpole, Thomas . . . Windsor Lodge, Seafield-av., Monkstown, Co. Dublin.

1875 White, Henry Vincent . County Surveyor, Queen's Co., Ballybrophy.

1874 Willson, Frederick Richard Thomas, B.E. Lake View, Kilrea, Co. Londonderry.

1897 Wilson, John George . . Kylasse, Chalvey Park, Slough, Bucks.

1876 A ⎱ Wise, Berkley Deane, M.Inst.
1880 M ⎰   C.E. (*Member of Council*) Silverstream House, Green-island, Belfast, and Belfast and Northern Counties Railway.

1871 Wright, John Arthur (*F.L.M.*) Cadiz Water Works, Sto. Cristo 4, Cadiz.

ASSOCIATE MEMBERS.

(*Assoc. M. Inst. C.E.I.*)

1897 A ⎱ Acton, John Henry . Civil Eng. Staff, East Indian
1899 A.M. ⎰   Railway, Calcutta.

1895 A ⎱
1899 A.M. ⎰ Ashworth, Charles Herbert 42 Dame-street, Dublin.

1879 A ⎱ Barnes, Robert Samuel Durban Club, Durban, Natal,
1899 A.M. ⎰   Wemyss, Assoc. M. and 16 Balls-road, Claugh-
    Inst. C.E, ton, Birkenhead.

ELECTED

1900	Barnes, Robert Stephenson, junr.	Tatestown, Navan.
1888 A 1899 A.M.	Barry, William Fitzgerald, Assoc. M. Inst. C.E.	County Surveyor, Monaghan ; Town View, Monaghan.
1900	Blake, John . . .	Engineer's Office, Gt. N. Ry., Amiens-street., Dublin.
1902	Browne, Henry . .	1 Cumberland-terrace, Birr.
1902	Butler, Rudolph M. .	12 Dawson-street, Dublin.
1901	Byrne, John Joseph .	Engineer's Office, Grand Canal, Dublin.

1903	Carnegie, Frank Alex. Somerville, B.A., B.A.I.	Kenilworth Cottage, Rathgar, Dublin.
1902	Clancy, Chas. B. . .	Glencar, Clontarf, Dublin.
1901	Colaco, Alinsio Leonard (*F.L.A.M.*)	9 Hornby-road, Fort, Bombay.
1901	Crawcour, Chas. Edward Stuart	Rathangan House, Co. Kildare.

1896 A 1899 A.M.	Delaney, James . .	County Surveyor, King's Co. Tullamore.
1898 A 1899 A.M.	Dillon, J. Trevor .	R. E. Office, Armagh.
1900	Douglas, Charles K. .	Rathmolyon, Enfield, Co. Meath.

| 1896 A
1899 A.M. | Evans, Richard . . | 53 South Mall, Cork. |

1896 A 1899 A.M.	Fitzgerald, Cecil Henry (*F.L.A.M.*)	Assistant City Engineer, Georgetown, Demerara, British Guiana.
1903	Fleming, John Joseph .	Mount View, John's Hill, Waterford.
1895 A 1899 A.M.	Forsyth, Thomas . .	5 Royal-terrace, Fairview, Dublin.

ELECTED

1887 A 1899 A.M.	Gaffney, Francis Sebastian, Assoc. M. Inst. C.E.	Colonial Engineer's Office, Singapore, S.S.
1902	Galbraith, A. de Rohan .	Town Hall, Portsmouth
1903	Galbraith, Lionel Norman (*F.L.A.M.*)	Gold Coast Government Railways, Sekondi, W. Africa.
1903	Galbraith, Fred. Victor	Gold Coast Government Railways, Sekondi, W. Africa.
1898 A 1902 A.M.	Hargrave, Wm. Harrison	Post Office, Kildare.
1896 A. 1901 A.M.	Harris, Herbert T. . .	30 Parliament-street, Dublin.
1902	Hughes, R. Lloyd . .	35 St. Mary's-road, Dublin.
1900	Hurley, Hugh Stanislaus .	Park House, Athy.
1902	Inglis, John Joseph .	Town Hall, Naas.
1896 A 1899 A.M.	Jackson, James Thomas .	Greenville Lodge, Upper Rathmines, Dublin.
1902	Kerr, Henry Forrest .	39 Clarinda-park, West, Kingstown.
1902	Krishna, Nil, Sen. (*F.L.A.M.*)	Calcutta.
1901	Leask, Henry Norman .	Englefield, Hartington-road, Chorlton-cum-Hardy, Manchester.
1903	Maxwell, Alexander. .	77 Grove-park, Rathmines, Dublin.
1903	M'Candliss, John C. .	8 Erskine-street, Newry.
1890 A 1899 A.M.	MacGarvey, Howard .	Lombard-street Works, Dublin.
1903	M'Grath, Joseph P. .	100 Leinster-road, Rathmines
1902	Magill, Joseph Ponsonby	Beaufort, Co. Kerry.
1894 A 1899 A.M.	Moore, George Tighe .	184 Gt. Brunswick-street, Dublin.
1880 A 1899 A.M.	Moyers, Sir George, . LL.D.	8 Vesey-place, Kingstown.

ELECTED		
1901	O'Connell, James . .	Altmuish Cottage, Kilmainham Wood, Co. Meath.
1903	O'Neill, Thomas J. .	19 Crumlin-road, Belfast.
1901	O'Sullivan, Patrick F. .	Tolka View, Richmond-road, Fairview, Dublin.
1902	Pansing, John . . .	Church-hill, Wicklow.
1897 A 1900 A.M.	Richardson, Thos. Henry	c/o Grindley and Groom, Calcutta.
1887 A 1902 A.M.	Rochford, John . .	4 Clarinda-park, West, Kingstown, and Board of Irish Lights.
1903	Roe, George Deane .	11 Crofton-avenue, Kingstown.
1901	Sheehy, Bryan Edward Fitzgerald.	50 George-street, Limerick.
1893 A 1899 A.M.	Spence, Arthur Wm. .	11 Brighton-avenue, Rathgar, Dublin.
1902	Stewart, Pakenham Thos.	33 Waring-street, Belfast.
1902	Taylor, Henry Thomas .	24 Fountain-road, Devonshire Park, Birkenhead.
1901	Travers, Frank V. J. .	Butlerstown House, Timoleague, Co. Cork.
1890 A 1899 A.M.	Warren, George Gates .	
1902	Whieldon, Arthur Wilkinson.	Berkeley-villa, Sutton, Co. Dublin.

ASSOCIATES.

(*Assoc. Inst. C.E.I.*)

1896	Allen, William Henry . .	The Terrace, Ennis.
1884	Anderson, Wm. (*Member of Council*)	9 Upper Sackville-street, and Glenavon, Merrion-road, Dublin.

1896	Benson, William Arthur Sanders	Cape Government Railways, Uitenhage, Cape Colony.
1895	Bingham, Charles H.	Messrs. Tedcastle, M'Cormick, & Co., Dublin.
1898	Bolton, Samuel H. (*F.L.A.*)	2 Hume-street, Dublin.
*1902	Browne, George	46 Rathgar-avenue, Co. Dublin.
*1902	Callaghan, Alfred J., LL.D.	11 Northumberland-road, Dublin.
*1901	Clayton, Henry F.	49 Mid. Abbey-street, Dublin.
*1903	Cornwall, Alfred M.	Thomasfort, Ballygar, Co. Roscommon.
1896	Cuttriss, Alfred W. M.	R. E. Dept., Buncrana, near Londonderry.
1889	Deane, Louis E. H.	Local Government Board Dublin.
1896	Espinasse, James	c/o Standard Bank of South Africa, Cape Town.
1883	Evans, James	27 Rutland-square, Dublin.
1874	Falkiner, Nathaniel L.	Port Chalmers, New Zealand,
1881	Fleming, Henry	Chicago, U.S.A.
1885	Gill, Robert Paul	30 Castle-street, Nenagh.
1895	Gilcriest, John Fawcette	Wine-street, Sligo.
*1901	Gordon, C. W.	53 Northumberland-road, Dublin.
1879	Gray, William Armroyde	New York.
1896	Hewitt, Wm. Tyrrell O. B., F.R.G.S.	West Indian Club, Howard Hotel, Norfolk-st., London, S.W.
1897	Higginbotham, Fred. Wm.	9 Lr. Sackville-street, Dublin.
*1902	Hollywood, Alexander	

* Marked thus are Non-Corporate Associates.

1896 Kelly, Cecil Fletcher . . Johnstown House, Athlone.

1895 Lamon, Thomas W. . . Newtownards, Co. Down.

1885 Maguire, William Robert . Tower Hill, Dalkey, and 10 Dawson-street, Dublin.
1867 Martin, Charles E. (*L.A.*) . 82 North Wall, Dublin.
1888 Martin, John E., B.A., T.C.D. . 82 North Wall, Dublin.
    (*L.A.*)
1890 Martin, Thomas P. (*L.A.*) . 82 North Wall, Dublin.
1903 M'Ardle, Arthur Andrew . Wesley Villa, Sydenham, Belfast.
1898 M'Cann, Walter . . . Town Surveyor, Drogheda
1895 M'Caw, George Tyrrell . . Taghnevan, Lurgan.
1893 M'Kenzie, Colin Douglas . . R. E Office, Ebrington Barracks, Londonderry.
1903 Mooney, Frederick Morgan . 118 Pembroke-road, Dublin.
1898 Morris, Ernest Horatio . . 43 Dame-street, Dublin.
1892 Mulville, Michael Walsh . . Court-road, Listowel, Kerry.
1881 Murphy, William M. . . Dartry, Rathmines, Dublin.

*1900 Nolan, Edward P. . . . The Quoile, Downpatrick.

1897 O'Kelly, W. H. . . . Sion House, Glenageary, Co. Dublin.
1893 Owen, Charles Austin . . 29 Molesworth-street, Dublin.

*1903 Palmer, J.E. . . . . Rose Lawn, Ballybrack, Co. Dublin.
1861 Patterson, Benjamin Thomas . 95 Lr. Leeson-street, Dublin.
1895 Phillipson, Burton R. . . Calgarth, Dalkey, Co. Dublin.
1888 Power, James Talbot, D.L. Leopardstown Park, Co.
    (*L.A.*) Dublin.

. * Marked thus are Non-Corporate Associates.

1895 Reinhardt, John . . . Qui-si-sano, Newtown-a
        Blackrock, Co. Dublin.

1892 Stuart, William Henry . . Cloonamore, Ballaghade
        Co. Mayo.

*1901 Tatlow, Joseph . . . M. G. W. Ry., Broadstor
        Dublin.

1887 Tresilian, Richard S. . . 9 Sackville-street, Uppe
        Cumnor, Eglinton-ro
        Donnybrook, Co. Dub

*1899 Wakeman, Wm. James Perrin . 117 Cave Hill-road, Be
1888 Wallace, Charles H. . . 35 Dame-street, Dublin.
*1902 Waring, Henry . . . Shanagarry, Miltown,
        Dublin.
1887 Watson, Charles W. . . Hollywood House, Prince
        Melbourne, Australia.
1891 Whiteford, James . . 28 Waring-street, Belfast.
1867 Woodward, Richard Caleb . Brisbane, Queensland.
1881 Worthington, Robert . . 40 Dame-street, Dublin.

* Marked thus are Non-Corporate Associates.

NOTE—*L.M., Life Member ; F.L.M., Foreign Life Member ; L.A.M., Life Asso
Member ; F.L.A.M., Foreign Life Associate Member ; L.A., Life Asso
F.L.A., Foreign Life Associate.*

STUDENT.

Wilson, Hezlitt Hamilton . . . Ardganah, Ballsbridge,
        Dublin.
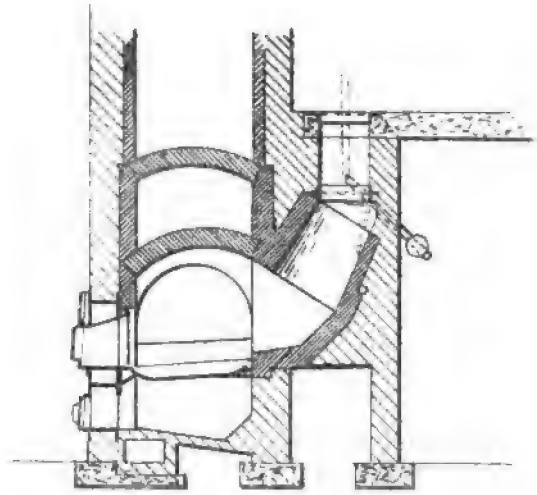
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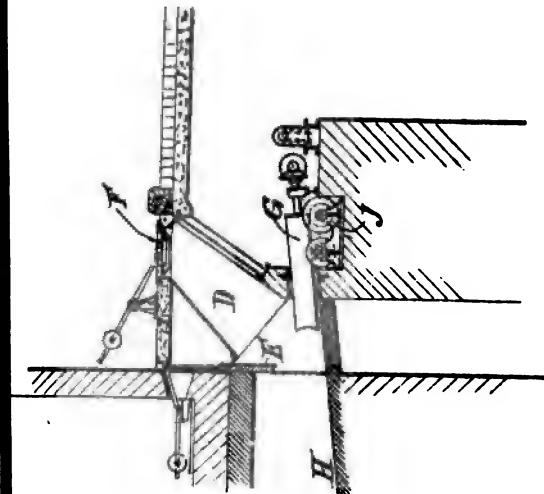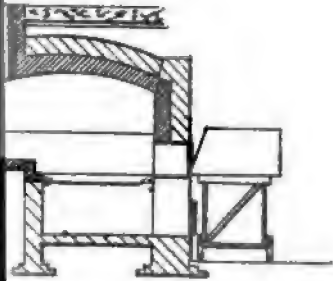
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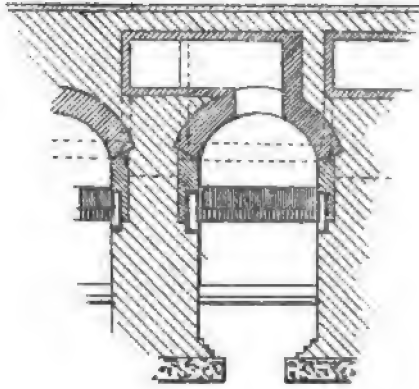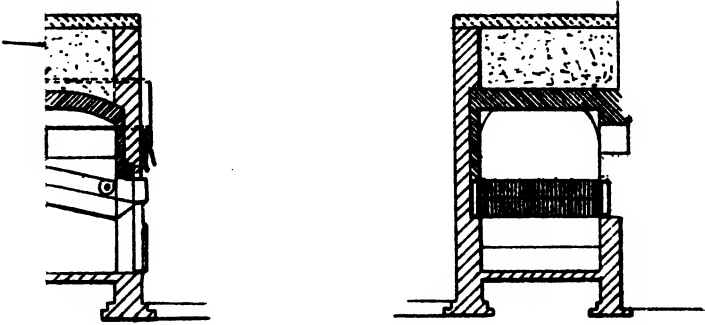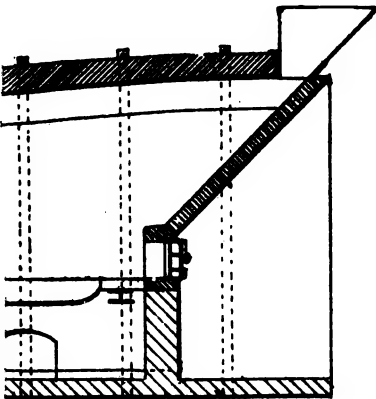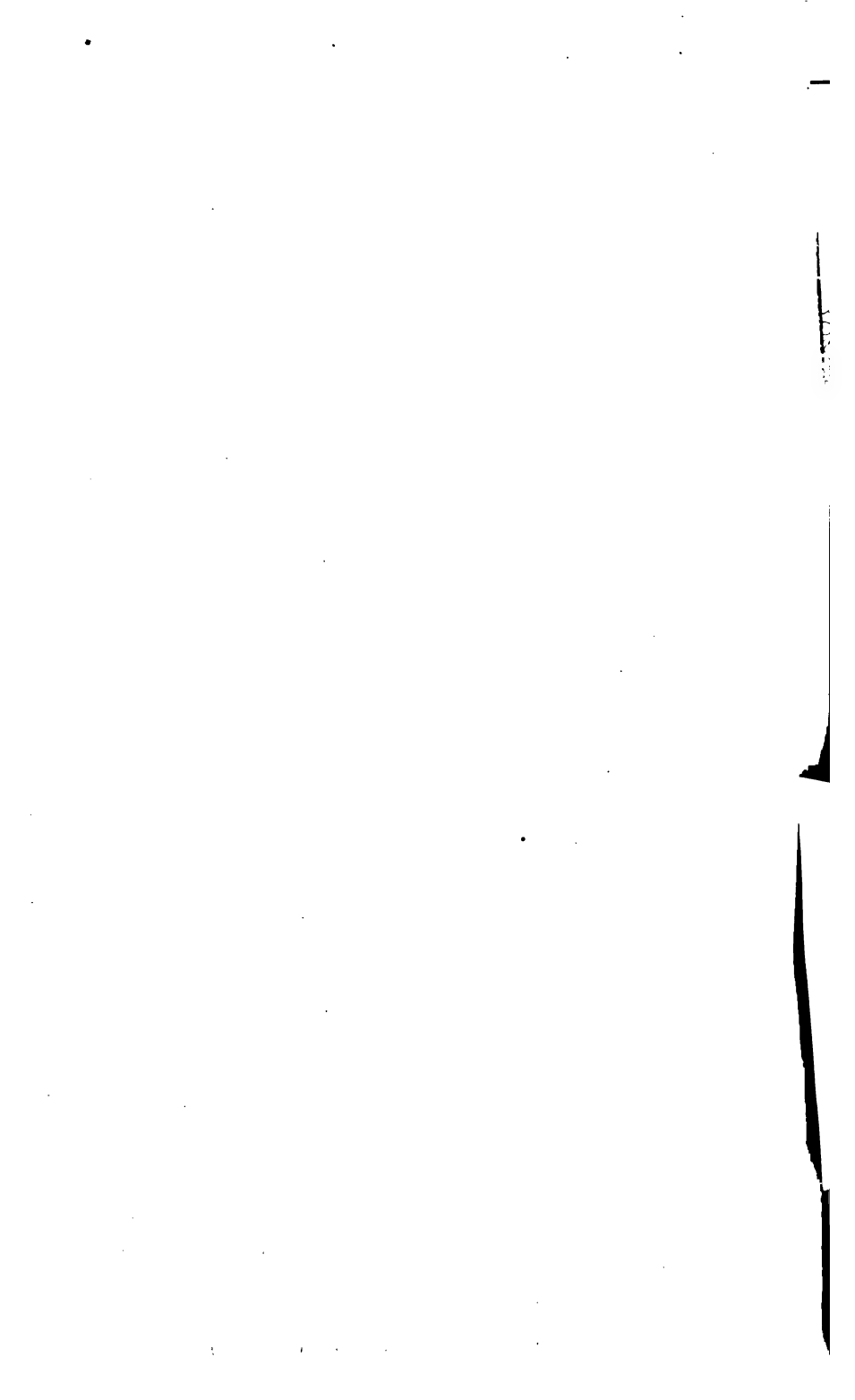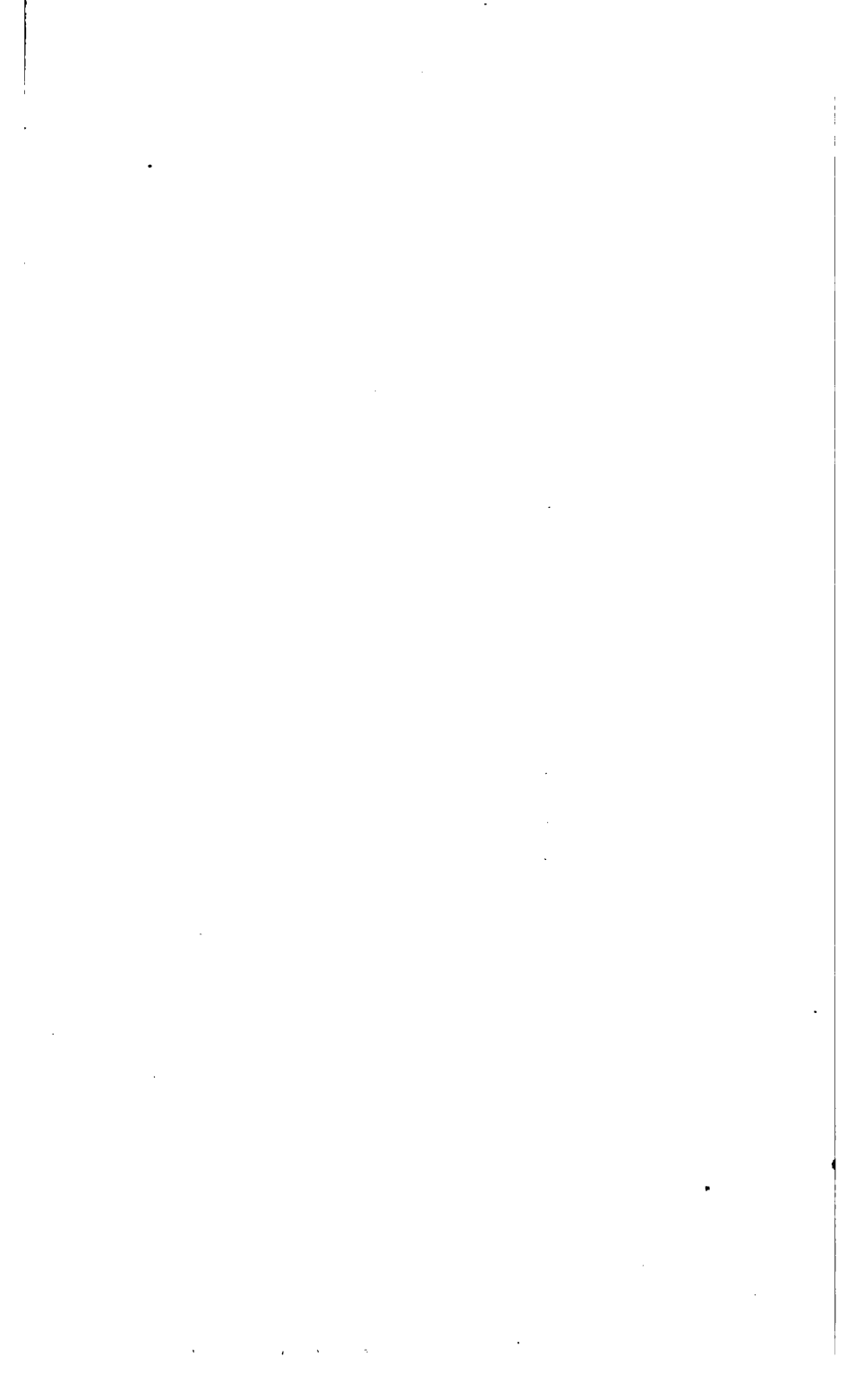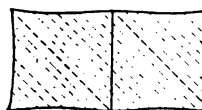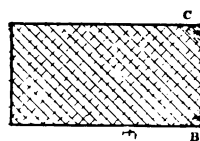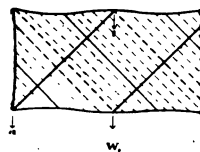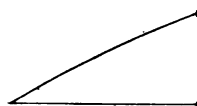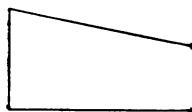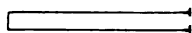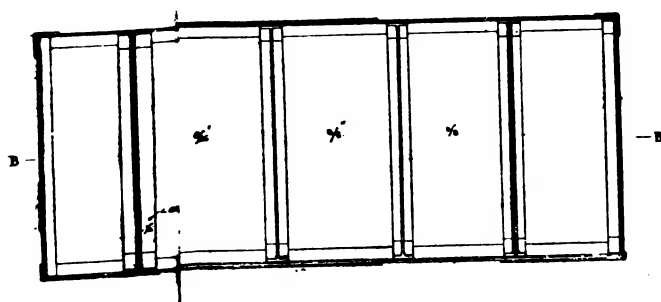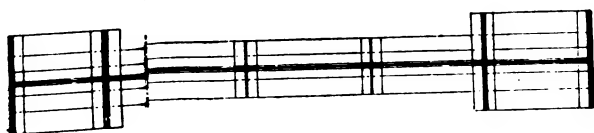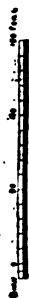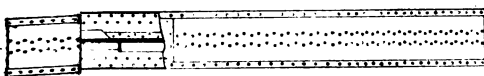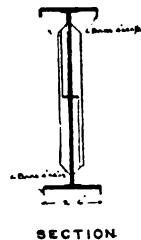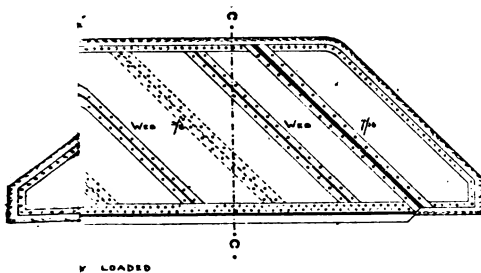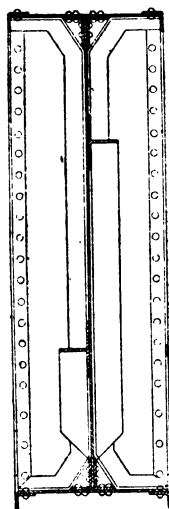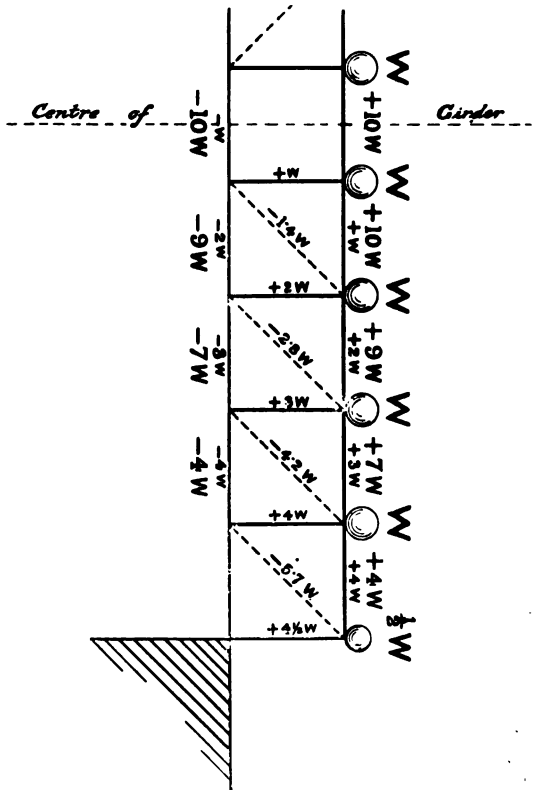
Fig. 2

Fig. 3

4

Y   · A

CROSS SECTION AA

SECTION

IF LOADED

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Groyne 11.
436.5'

Groyne 12.
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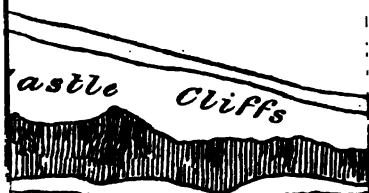
Groyne 10. 441·5'

Groyne 11. 436·5'

Groyne 12. 401'

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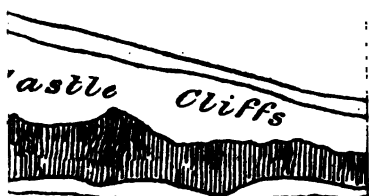
PLATE XII.

Fɪɢ. II.—View taken July, 1900, before Completion of Embankment. Piles are seen standing up in rows.

PLATE XIII.

Fig. III.—View taken July, 1902, from same position as in Fig. II., and looking in same direction (*vide* clump of trees). Top of Embankment barely visible.

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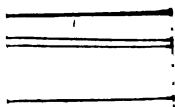
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Recession of H.W. 136'
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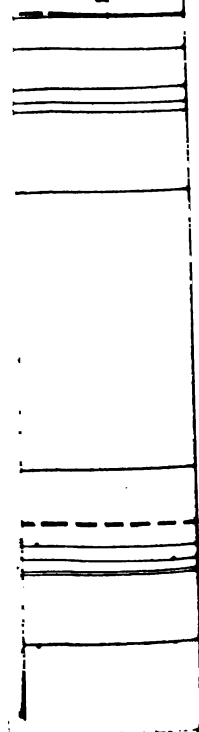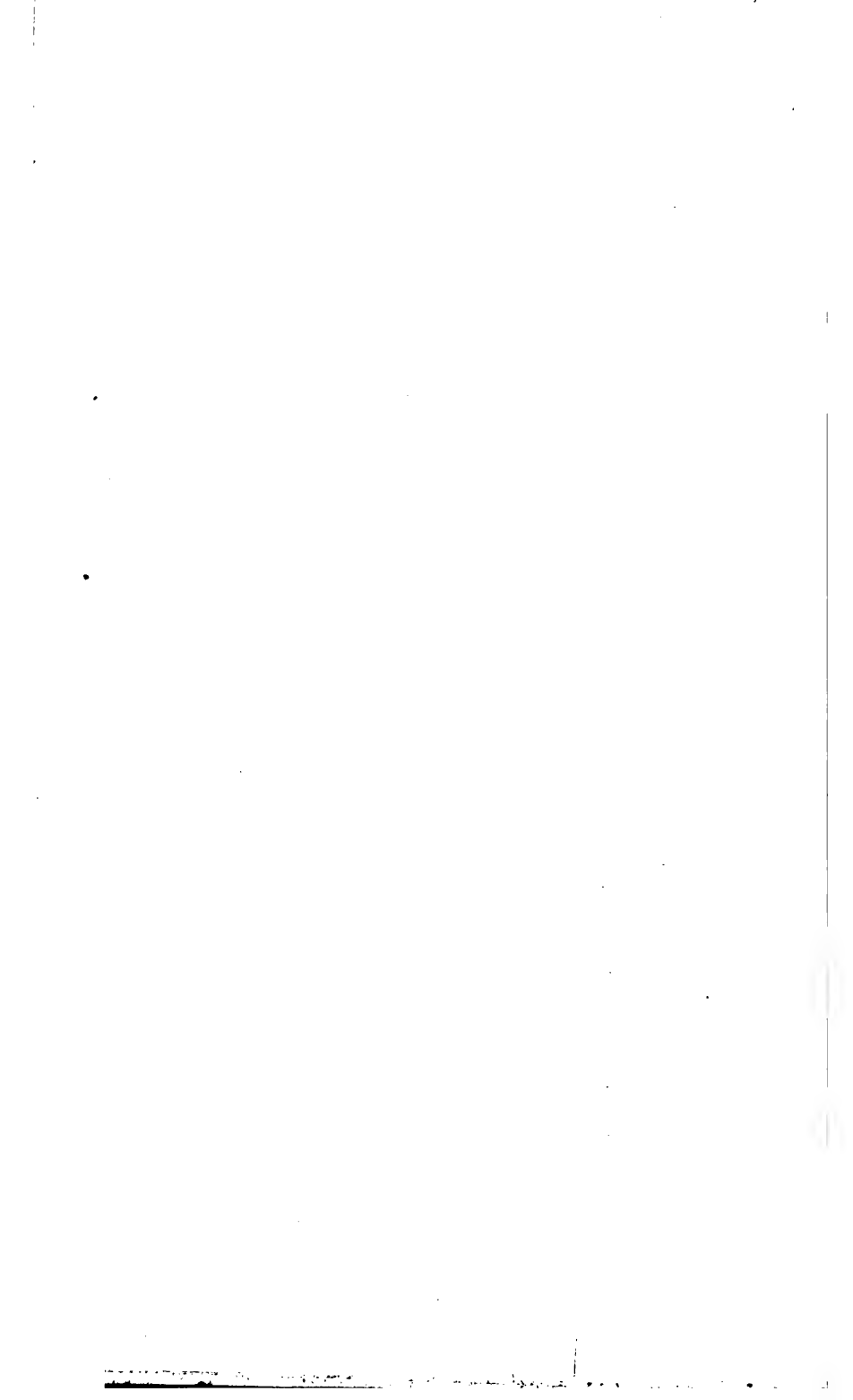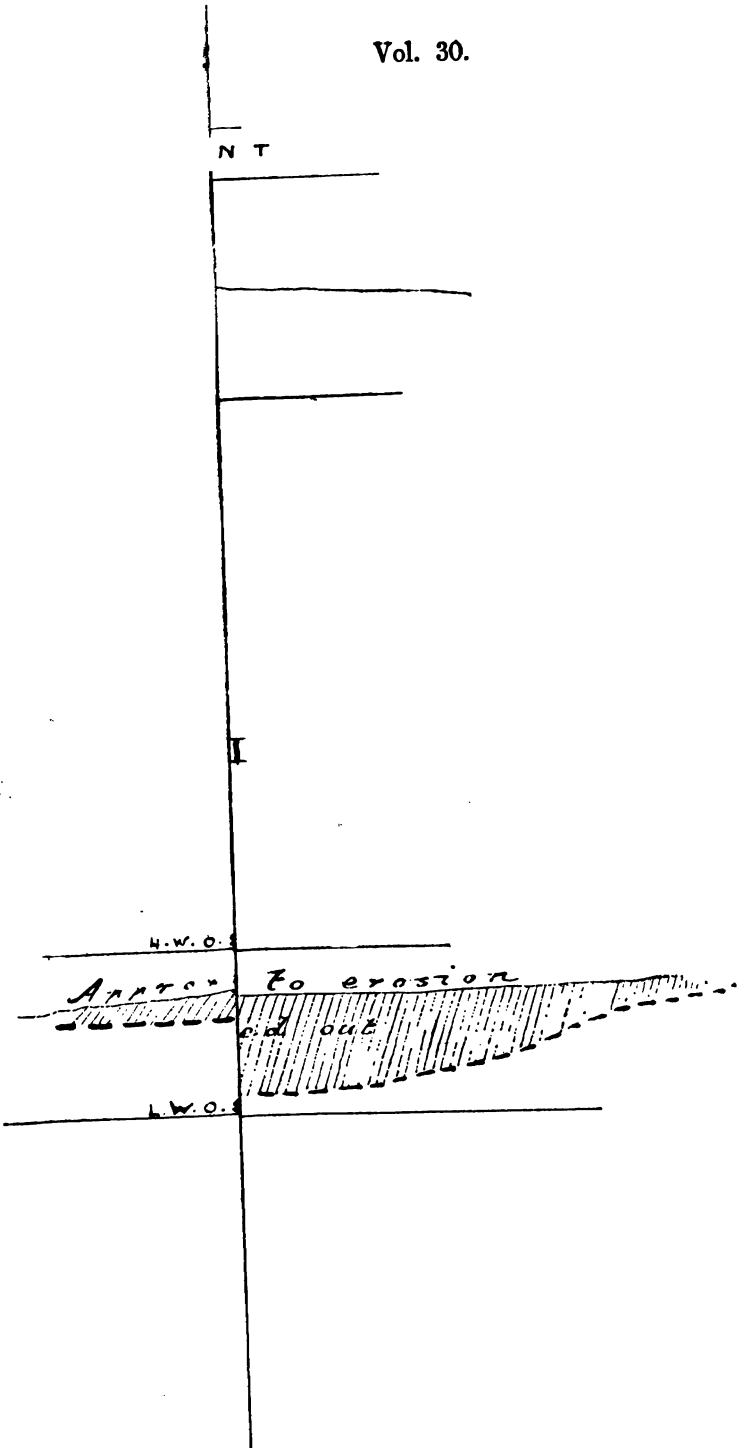
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Fig. VIII

Broken Tram pin

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Fig X

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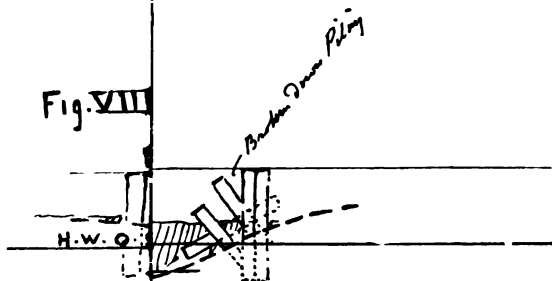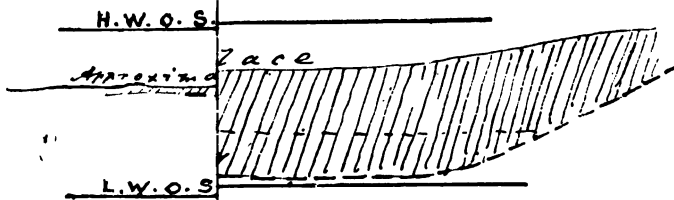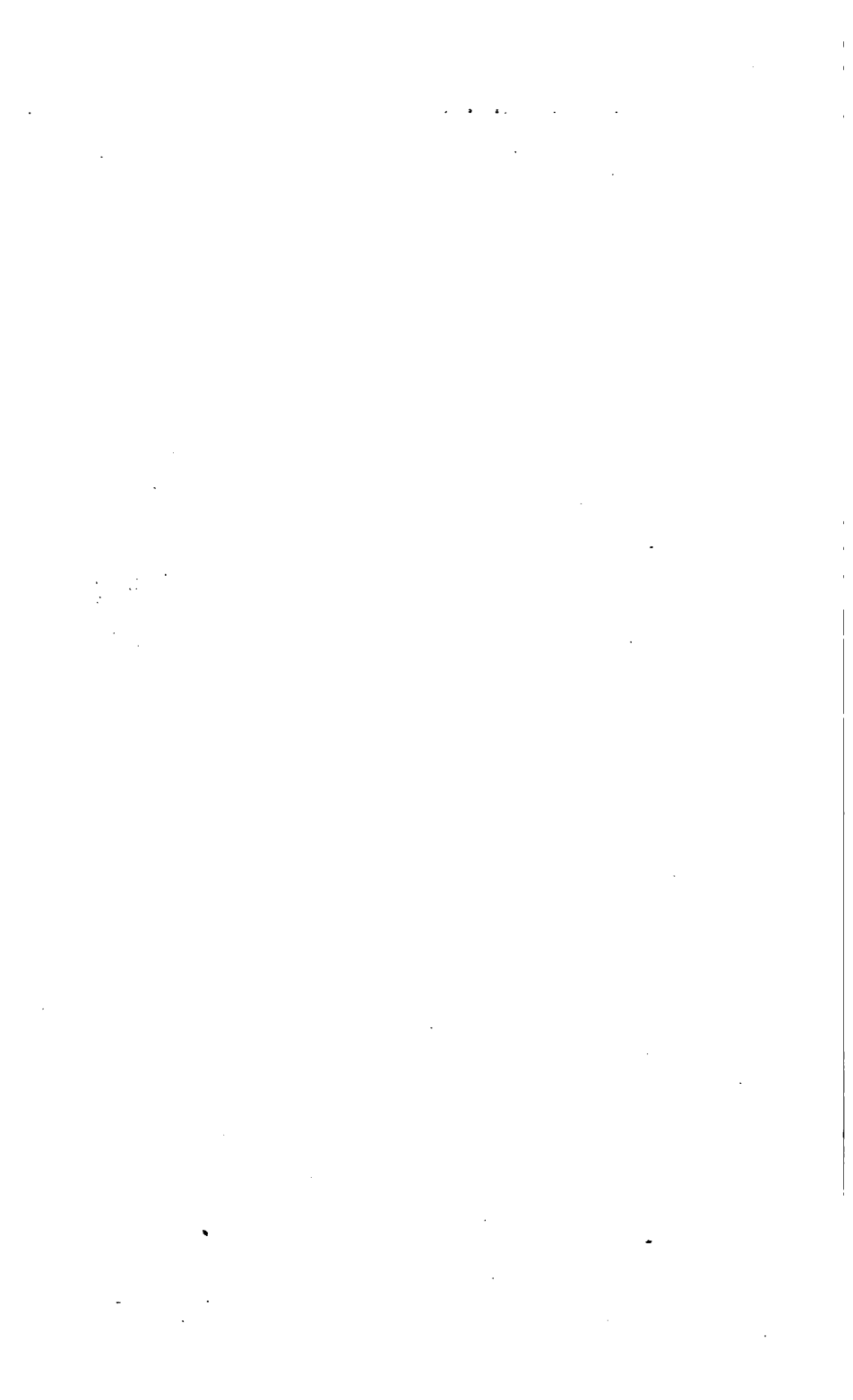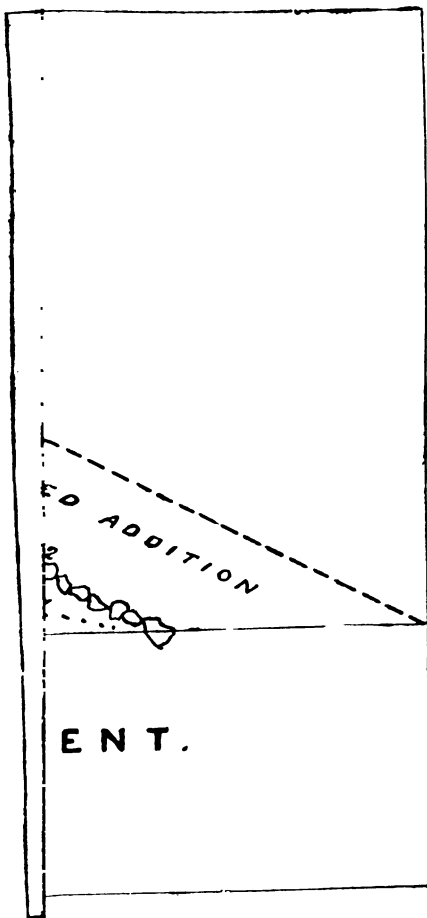
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